1985

PRICE DISCOVERY FOR US AND EC CORN GLUTEN FEED AND RELATED MARKETS

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Journal Article J- of the Purdue Agricultural Experiment Station.

AAEA paper, 1985

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Abstract

The dynamic relationship of US and EC prices of corn gluten feed and related markets are investigated using time series models. Results show prices for Rotterdam corn gluten feed and soybean meal markets are instantaneously related, and that these commodities behave as strong substitutes. Results also show prices for these commodities are first discovered in Europe, rather than in the US. Rotterdam corn gluten feed and Rotterdam soybean meal behave as weak substitutes for West German barley. Thus, the results indicate that corn gluten feed acts more like a protein supplement than a feed grain or energy substitute.

Keywords: causality tests, barley prices, corn gluten feed prices, multipliers, price discovery, soybean meal prices, time series.

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FEED AND RELATED MARKETS

Corn gluten feed (CGF) is a by-product of the corn refining (wet milling) industry, which produces high fructose corn syrup (HFCS). This industry has grown rapidly in the United States since the mid-1970's. Consumption of HFCS has increased from 1.5 to 14 kilograms per capita from 1973 to 1984. During this same time period, per capita consumption of all sweeteners (sugar, HFCS, and glucose) has remained relatively constant. Much of this increased demand for HFCS has occurred due to its competitive price relative to sugar. Since 1982, the US domestic sugar program and import restrictions have kept the price of domestic refined sugar at twice the level they would have been without the restrictions (USDA, 1984). During 1983, US sugar price averaged $US 33.00, while HFCS-42 averaged only $US 19.21 per cwt (USDA, 1984). Since corn gluten feed is a by-product of the corn refining industry, its production has increased at the same rate as HFCS.

CGF is produced primarily in the United States. However, its primary market is the European Community (EC), where it is used for hog and cattle feed. In contrast to the US, grain price relationships within the EC have permitted its widespread use, as over 90 percent of the CGF produced in the US is exported to the EC. From 1974 to 1984, US exports of CGF increased from .6 to 3.5 million MT with a value of $US 800 million. The US maintained a 95 percent market share of EC CGF in 1983 (Agra Europe, October 12, 1984).

Within the EC, feed compounders use a variety of commodities including citrus pulp, grain and milling by-products, oilseeds, and CGF. The imported commodity of primary interest in this study besides CGF is soybean meal. Both soybean meal and CGF enter the EC without import restrictions under the Dillon Round of GATT. Unlike CGF, soybean meal is not a relatively new import to the EC. Over the last six years, US soybean meal annual exports have held relatively constant averaging slightly over 6 million MT.

The sudden increase of CGF imports by the EC from the mid-1970s to mid-1980s has created controversy. European grain producers argue that CGF imports displace their production. EC wheat and coarse grain production has increased by around 40 percent while at the same time stocks have about doubled from 1977 to 1984. As a result, the EC Council of Ministers has approved a proposal to limit CGF imports to 3 million MT annually, with a heavy import levy for imports exceeding this amount (Agra Europe, August 3, 1984). This action has prompted US officials to consider retaliatory measures against French dairy products, French wine, and Italian wine exports to the United States (Agra Europe, June 15, 1984).

The question of whether or not or to what extent CGF imports displace EC grain production has created two opposing views. One view is held by some farmers and others within the EC. It essentially contends that the high energy-low protein content of CGF causes it to behave as an energy rather than protein substitute. Thus, they hold that soybean meal and CGF behave as weak substitutes (or as complements). Therefore, they see CGF imports as displacing their domestic grain supplies, and thus contributing to EC grain surpluses. An opposing view held by some in the US is just the opposite. It holds that based on this same energy-protein level, EC soybean meal and CGF are strong substitutes as they argue that CGF is low energy-high protein. Therefore CGF imports do not displace EC grain. This view is supported by a USDA study concluding that EC CGF imports compete with protein meals such as soybeans (Agra Europe, March 23, 1984).

The above opposing views are both primarily based on technical protein-energy relationships rather than economic or price relationships between soybean meal and CGF. This technical relationship is that soybean meal contains 44 percent protein while CGF contains about twenty-one percent protein, while grains contain even less protein than CGF. The "EC view" holds that the 21 percent protein level of CGF is "relatively low", compared to the 44 percent level of soybean meal, therefore qualifying it as a low protein-high energy feed substitute. On the other hand, the "US view" holds that the 21 percent protein level is "relatively high", thus qualifying CGF as a high protein feed substitute. Therefore, based primarily on this technical protein and energy information, views may be incorrectly established as to whether or not CGF and soybean meal behave economically as substitutes. The objective of this paper is to determine whether or not CGF behaves economically as a substitute or a complement in relation to both soybean meal and feed grains. This is accomplished by studying the price discovery process for these commodities.

International price discovery for CGF and related commodities is also of interest to policymakers and those in the international commodity trade. On one hand, US CGF price may be discovered primarily on the supply side, by US corn price, as it is a corn by-product. On the other hand, CGF price may be discovered on the demand side by the EC CGF market. The extent to which CGF and soybean meal prices are discovered by the supply (US) or demand (EC) side forces will be examined.

The results relate to the question of market efficiency, in terms of the time for information to fully flow from one market to another. If prices are slow to adjust to exogenous shocks, then price adjustments are slow, thus reflecting inefficiencies in the markets (Fama). Previous market efficiency studies have investigated whether or not prices fully reflect information contained in their own past prices (Gupta and Mueller, 1982b). Studies have also investigated whether or not prices fully reflect information of past prices of related commodities (Brorsen, et al., 1984; Gupta and Mueller, 1982a).

The methods used in this paper are similar to Brorsen, et al. This procedure utilizes a time series model. It emphasizes price discovery, or the process by which equilibrium price is reached. This is in contrast to a structural model, which emphasizes price determination, or what the equilibrium price level will be. With only about 10 years of reliable CGF data available, the time series model does not suffer from the degrees of freedom problem which would be associated with an annual structural model.

Theoretical Model

A theoretical model involving the trade of a commodity is presented here. Excess supply and excess demand functions in time t are

(1) $E_t^S = f(P_t^S, U_t)$,

(2) $E_t^D = f(P_t^D, V_t)$, and

(3) $E_t^S = E_t^D$

where E^S and E^D represent the excess supply and demand quantity functions, P^S and P^D are the corresponding prices, while U and V represent the excess supply and demand shifters, such as weather and income.

Assuming trade occurs, structural static equations (1), (2), and (3) can be solved for the equilibrium trading price. This yields the reduced form equation:

(4) $P_t^e = f(\Theta_t)$

where P^e is the equilibrium price with trade and $\Theta = (U,V)$. This reduced form equation is the general equilibrium condition which can be used to analyze price when markets are in equilibrium. Price is expressed as a function of excess supply and demand shifters (i.e., weather, income).

However, assuming the market is not in equilibrium, then $E^S \neq E^D$. Disequilibrium may occur, for example, when firms do not make instantaneous adjustments in response to a changing market situation. If disequilibrium occurs, then the static price equation (4) can be made dynamic by including both present and past structural shifts:

(5) $P_t = f(\Theta_t, \Theta_{t-1} \ldots \Theta_q)$.

If markets do not adjust instantaneously to a particular shock, they would be expected to adjust to a new equilibrium within a relatively short period of time. This adjustment process can provide useful information on the price discovery mechanism and the characteristics of a market.

However, it is impossible to measure or take into account of all the excess supply and demand shifters for any short period of time. Therefore, rather than using equation (5), a superior approach is to assume that price is determined by some underlying stochastic process related to Θ. This process can then be modeled indirectly using a time series model:

(6) $P^e_t = D + S + e_t$

where D represents the deterministic component and $S + e_t$ the stochastic process. The deterministic component, which represents trend and seasonality, must be removed. The stochastic process can then be identified and estimated using time series modeling.

Data and Procedure

Data in Europe are weekly Rotterdam (C.I.F.) prices for soybean meal (44 percent protein) and CGF (21 percent protein) (Oil World Weekly).

Barley prices (paid by feed manufacturers, etc.) are from W. Germany (<u>Agra Europe</u>). Chicago prices are used for U.S. soybean meal, CGF (<u>Oil World Weekly</u>), and corn (#2YC) (Dunn & Hargitt). All prices are cash and $US per MT. A reliable Rotterdam CGF price series was unavailable prior to January 1, 1978. Therefore, the data are for January 1, 1978 to the first week of April 1984, for a total of 329 observations.

First differences of the data are taken to remove any linear time trends. Seasonality is also checked using periodograms. A series of bivariate autoregressive (AR) models are used, as the more general autoregressive moving average (ARMA) model can be written as an AR if the MA process is invertible. AR models are simpler to estimate and analyze than ARMA models. Since model selection in a multivariate AR model is better developed and requires less pretesting, the AR is selected over the more general ARMA. These are used in the causality and multiplier procedures which follow. The order of the models are selected using Akaike's Information Criterion (AIC) (Akaike). The AIC tends to overestimate the true order of the model thus lessening the probability of selecting too small an order in a small sample (Shibata).

The bivariate model can be written as

$$(7) \quad \begin{bmatrix} P_{t} \\ P_{t} \end{bmatrix} = \sum_{i=1}^{p} \begin{bmatrix} a(i) & a(i) \\ a(i) & a(i) \end{bmatrix} \begin{bmatrix} P_{t-i} \\ P_{t-i} \end{bmatrix} + \begin{bmatrix} e_{t} \\ e_{t} \end{bmatrix}$$

where P and P are the prices of the commodities, p is the order of the model, the e's are residuals, and the a's are coefficients to be estimated.

Residuals of the bivariate autoregressive models are checked for white noise by Fisher's Kappa and Bartlett's Kolmogorov-Smirnov tests (Fuller, pp. 284-86). Assuming the true AR model is selected and the residuals are white noise, then consistent and asymptotically efficient estimates of the parameters and standard errors are obtained by least squares techniques.

The concept of Granger causality is used to determine the direction of dynamic price adjustments. Pierce and Haugh define causality in terms of predictability. A variable X does not cause variable Y if Y can not be predicted better by using past values of X than if past values of X are not used. If X causes Y and Y does not cause X, then X is said to unidirectionally cause Y. Bivariate causality occurs when X causes Y and Y causes X. This is called a feedback relationship. Unidirectional causality has implications for price discovery. For example, if Rotterdam prices cause Chicago prices unidirectionally, it would imply that prices are first discovered in Rotterdam.

The test for causality running from X to Y is performed by testing the significance of the coefficients as a group rather than individually. This test is conducted with the Wald F statistic (Wald):

$$\text{(8)}\quad \text{Wald } F = \frac{(R\tilde{\beta}-r)'[\tilde{\sigma}^2 R(X'X)]^{-1}(R\tilde{\beta}-r)}{p} \sim F(p,T-(2p+1))$$

where $R\tilde{\beta}-r$ corresponds to the relevant restriction and $\tilde{\sigma}^2$ is the variance of unconstrained $\tilde{\beta}$ and p is the number of restrictions. This test procedure is a variant of Granger's test which Monte Carlo studies have shown to be more powerful than the causality tests of either Sims (1972, 1977) or Haugh (Nelson and Schwert; Geweke, et al.).

The causality tests previously mentioned provide no information about the dynamic properties of the model, i.e., how the impact of price changes are transmitted through the markets. They do not show the net impact of one market on another. In a multimarket framework, a price change in one market has both a direct and indirect impact on other markets. An autoregressive model is a parsimonious representation of a dynamic process, thus the order of the autoregressive model underestimates the time period for full adjustment. Therefore, the dynamic properties of the underlying series are further examined by calculating dynamic multipliers for the bivariate autoregressive models (Chow, 1975, pp. 106-08, 153-56).

The traditional interpretation of dynamic multipliers is not used in this analysis. Dynamic multipliers typically measure change in the endogenous variable with a one unit change in an exogenous variable. In this analysis, all predetermined variables are lagged endogenous variables; and dynamic multipliers are calculated, assuming a one-time stochastic shock occurs through the error term. This shock is related to e_t in equation (6), but this shock is not specified as to whether it is due to a shift in supply or a shift in demand. The multipliers thus show the dynamics of a price change due to an unspecified random disturbance or a shift in an exogenous variable.

The one-time shock occurs through the error term in the autoregressive model for deseasonalized price changes. Ths shock results in an immediate change in current price (P_t) and also a change in the expected value of future price changes. The m^{th} delayed run multiplier (DRM(m)) shows the impact of this one-time shock in time t on expected price changes in time t+m. Thus,

$$(9)\quad DRM(m)_{ij} = \frac{\partial E[\Delta P_i(t+m)]}{\partial P_j(t)}$$

where $DRM(m)_{ij}$ is the delayed run multiplier measuring impact on the expected change in price i in time period t+m of a change in price j in time t.

The intermediate run multiplier (IRM(m)) is the sum of delayed run multipliers 1,...,m. The intermediate run multiplier thus represents the total change in expected price changes which is the change in the expected price level m time periods ahead. The long run multiplier is the impact on expected price when a new equilibrium is reached which is the same as the intermediate run multiplier as m approaches infinity. Long run multipliers (LRM), in this case, can be interpreted as

$$(10)\ LRM_{ij} = \lim_{h \to \infty} \frac{\partial E[P_i(t+h)]}{\partial P_j(t)} = \sum_{k=1}^{\infty} \frac{\partial E[\Delta P_i(t+k)]}{\partial P_j(t)} = \sum_{k=1}^{\infty} DRM(k)_{ij}$$

where LRM_{ij} is the long run multiplier measuring the long run impact on the expected value of price i of a change in price j in time t and $P_j(t)$ is price j in time t. Standard errors for delayed run multipliers were calculated following the method developed by Schmidt (1973). Standard errors for the long run multipliers were obtained as in Dhrymes (1973).

The period of adjustment implied by an AR model is longer than the number of lags. The speed of price adjustment is measured here using two alternative approaches. "Adjustment Period I" is defined here as the number of weeks it takes for the intermediate-run multiplier to reach and remain within five percent of the long-run multiplier (Ngenge). This is when all but five percent of the impact from a shock is reflected in the price. "Adjustment Period II" is defined here as the number of weeks it takes for the delayed run multiplier to become not significantly different from zero at the five percent significance level. The best measure of the speed of adjustment may be the minimum of the two measures, because the first tells when impacts are small and the second when impacts are no longer significant.

Results

Both Fisher's Kappa Test and Bartlett's Kolmogorov-Smirnov tests failed to reject the null hypothesis of white noise residuals in all 16 equations (Table 1). Therefore, these tests support the appropriateness of the modelling procedure. The causality F statistics, equation F statistics, and equation R^2 values are shown in Table 2. Six of the sixteen equations have significant F statistics at the five percent level, indicating significant explanatory power. Only two of the equations have an R^2 value over .20. This is not unexpected, as equations constructed from weekly data which is first differenced would not be expected to have near as high R^2 values as, for example, undifferenced annual data. Three of the price relationships, shown at the bottom of Table 2, had a zero order selected by the AIC, therefore no equations could be constructed nor could causality tests be performed.

All causality test results are shown in Table 2. However, those of particular interest are shown in Figure 1. Only those causality test results which were significant at the five percent level or results which have a zero order are reported here (Figure 1). As well all causality is one way, no feedback relationships are found. Chicago corn gluten feed price is "caused" (in the context of this paper's definition) or led by all other markets. On the demand side, Rotterdam CGF market leads it by 9 weeks. This lead would be expected, since nearly all CGF is exported to Europe. The Rotterdam soybean meal market also leads Chicago CGF, by 3 weeks, indicating this price also reflects information before the Chicago CGF price. On the supply side, Chicago corn price leads Chicago CGF price by 3 weeks. This lead would be expected, as CGF is a by-product of corn milling, so its price would also be affected by the Chicago corn market.

The Chicago soybean meal market leads the Chicago CGF market by 10 weeks, thus jointly discovering Chicago CGF price. Chicago CGF does not lead any of the other prices in price discovery, but rather it is led by the other prices.

The causality results also show that soybean meal and corn gluten feed prices are primarily discovered on the demand side, in Rotterdam, as opposed to the supply side, Chicago. This is evidenced by the causality tests showing both the Rotterdam CGF and Rotterdam soybean meal markets leading both the Chicago CGF and Chicago soybean meal markets, but not vice-versa. This result may be due to the large number of substitute commodities available to European feed compounders (i.e., citrus pulp, manioc, copra meal, etc.). Their plant machinery and mathematical programming techniques enable them to substitute rapidly from one commodity to another as relative prices change. This behavior may imply that those on the demand side (EC) obtain information on relative prices in advance of those on the supply side (US). This would cause Rotterdam prices to lead Chicago prices, as the results show. Thus, the effect of demand shifters appears to outweigh the effect of supply shifters in price discovery.

The nine week lead from the Rotterdam CGF market to the Chicago CGF market indicates a fairly long time period for information to fully pass from one market to another, indicating possible market inefficiencies. In contrast, information is passed from Rotterdam CGF to Chicago soybean meal in only 1 week. The other long information flow is from Chicago soybean meal to Chicago CGF, 10 weeks.

A zero lead between markets was found in a number of cases (Figure 1). This result indicates that neither market leads the other. Either the markets are instantaneously related or they are unrelated. The correlation of price changes (i.e., the first differenced data) between markets can help in determining whether the markets are instantaneously related or unrelated when combined with the zero lag result. A high positive correlation coefficient in price changes implies that the two commodities are strong substitutes. A high negative correlation implies the two commodities are complements. A low correlation (positive or negative) implies that the markets are unrelated or are not close substitutes or complements.

A set of correlation coefficients of price changes are presented in Table 3. Rotterdam CGF and Rotterdam soybean meal price changes have a positive correlation of .45, which is significant at the .0001 percent level. This result when combined with the zero lead indicates that Rotterdam soybean meal and Rotterdam CGF behave as strong economic substitutes rather than complements. This is supported by a previously cited USDA study (Agra Europe, March 23, 1983). Also, W. German barley along with Rotterdam soybean meal and CGF are weakly related as they have zero leads combined with low correlation coefficients of .15 and .20, respectively. This indicates that W. German barley acts as a weak substitute for Rotterdam CGF and soybean meal. This may partly be due to the government policy of controlling barley price within a narrow band, in contrast to Rotterdam soybean meal and CGF prices which are set by world market conditions. These results that Rotterdam CGF and soybean meal are strong substitutes for each other, but not for W. German barley lend support to the "U.S. view" of the debate. Rotterdam CGF behaves economically more like Rotterdam soybean meal, a protein substitute rather than like barley (or grain) an energy substitute. Thus, CGF may substitute for some European grain, but it primarily substitutes for protein feeds.

Another instantaneous relationship is Chicago corn and Chicago soybean meal price (Figure 1). These price changes have a positive correlation coefficient of .61, significant at the .0001 percent level. This indicates that the two commodities behave as strong economic substitutes, rather than complements. Chicago CGF and soybean meal do not have an instantaneous price relationship, as opposed to the situation in Rotterdam. This may be due to Chicago CGF being priced relatively high compared to soybean meal. It may be more economical for feeders in the US to utilize soybean meal instead of CGF. Yet in the EC, CGF may substitute for some of the expensive grain, making it more economical to use than soybean meal.

The multiplier analysis shows the direction, magnitude, and speed of price adjustment (Table 4). For example, the impact of Rotterdam soybean meal on Chicago CGF is .27 means that if soybean meal in Rotterdam increases $1.00, Chicago CGF will increase $0.27 in addition to any simultaneous increase. Positive multipliers imply commodities are substitutes, negative multipliers imply complements or weak substitutes. All multipliers which are significant have positive signs as expected implying all commodities are substitutes except for Chicago CGF Chicago soybean meal. Negative multipliers may indicate that the two commodities behave more as substitutes in the direction of causality than vice-versa. For example, Chicago soybean meal may be more of a substitute for Chicago CGF than vice-versa (i.e., water may be a better substitute for tea than vice-versa). All relationships with significant causality results also have significant multipliers. As well, the multipliers also support the causality results that CGF and soybean meal prices are discovered on the demand side of the market.

The two measures of the adjustment period calculated using the dynamic multipliers are also shown in Table 4. Adjustment period I shows the number of periods from an initial shock, such as weather, until all but five percent of the total impact on price is reflected. Considering only the positive and significant multipliers, Rotterdam CGF and Chicago SBM along with Rotterdam SBM and Chicago corn are the fastest to adjust, taking only one week. At the other extreme, Chicago CGF → Rotterdam CGF is slow to adjust, taking 25 weeks. This may be due to information traveling from Rotterdam CGF to Chicago soymeal and then to Chicago CGF. This range, from 1 to 25 weeks, shows that it takes from 1 to 25 weeks for information to fully flow from one market to another, depending on the commodity and location.

The other measure of the speed of adjustment, adjustment measure II, shows the number of weeks it takes for the delayed-run multiplier to remain not significantly different from zero. Compared to adjustment period I, this measure generally shows a longer period of adjustment. Again, the best measure of the period two is probably the minimum of the two, as the first tells when the impacts are small, and the second when the impacts are no longer significant. Taking the minimum of the two measures, it takes an average of 12 weeks for information to fully flow from the Rotterdam CGF and SBM markets to the Chicago CGF market. Similarly, it takes an average of 11.5 weeks for information to fully flow from the Chicago CGF and SBM markets to the Chicago CGF market. The multiplier results show that the markets have considerable inefficiencies in the time it takes for information to pass from one market to another. These inefficiency findings are relatively consistent with the causality results. The longer the causality lead time the longer are Adjustment Periods I and II. However, the multipliers generally show more market inefficiency or time for information to fully flow from one market to another, as would be expected.

Conclusions

The causality and multiplier results were found to be generally consistent. Chicago CGF price was found to lag all other markets in price discovery. Soybean meal and CGF price were found to be discovered first on the EC or demand side of the market rather than in the US or supply side of the market. This could be due to the large number of substitute commodities available to feed compounders, who become aware of these substitute commodity price changes before their counterparts in the US.

Rotterdam CGF and Rotterdam soybean meal were found to behave as substitutes. However, W. German barley was found to be only a weak substitute for these two commodities. This is in contrast to a view held by some within the EC and in support of the "US view". These results also support a USDA study. This substitute relationship implies that if CGF imports were to be restricted by the EC, they would primarily be replaced by soybean meal along with other protein substitutes, not by EC barley or grain. Therefore, the proposed CGF import restrictions may not assist in disposing of excess EC grain as proposed, but instead increase other imports such as soybean meal. This is consistent with a leading Dutch feed compounder who used linear programming and found that by allowing no CGF into its ration, the use of other proteins such as soybean meal, citrus pulp, and copra meal increased, while wheat and barley did not enter the ration, as their prices were too high (Agra Europe, March 23, 1984). The results provided by this paper, though not the final word on the subject, should be useful to policymakers and those within the commodity trade.

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Table 1. White Noise Tests of the Residuals from Causality Equations.[a]

Commodity	Bartlett's Kolmogorov-Smirnov Statistic	Fisher's Kappa
Rotterdam SBM[b] → Chicago CGF	.0630	5.81
Chicago CGF → Rotterdam SBM	.0397	6.14
Rotterdam SBM → Chicago SBM	.0569	5.19
Chicago SBM → Rotterdam SBM	.0487	5.20
Rotterdam CGF → Chicago CGF	.0353	5.65
Chicago CGF → Rotterdam CGF	.0278	4.33
Rotterdam CGF → Chicago SBM	.0614	5.92
Chicago SBM → Rotterdam CGF	.0449	3.78
Chicago Corn → Chicago CGF	.0481	6.22
Chicago CGF → Chicago Corn	.0349	4.01
Chicago SBM → Chicago CGF	.0434	3.92
Chicago CGF → Chicago SBM	.0291	5.56
Chicago Corn → Rotterdam CGF	.0654	6.12
Rotterdam CGF → Chicago Corn	.0514	4.71
Chicago Corn → Rotterdam SBM	.0619	5.06
Rotterdam SBM → Chicago Corn	.0536	4.63

a Both tests failed to reject the null hypothesis of white noise residuals in all 16 equations.

b SBM = soybean meal; CGF = corn gluten feed.

Table 2. All Weekly Price Causality Lead-Lag Relationships and Equation Results for Corn Gluten Feed, Soybean Meal, and Corn.

Commodity			Causality Wald F-statistic	Equation F-statistic	R^2
Rotterdam SBM[a]	→ 3[b]	Chicago CGF	8.94*	6.99*	.12
Chicago CGF	→ 3	Rotterdam SBM	.80	.59	.01
Rotterdam SBM	→ 4	Chicago SBM	14.38*	7.37*	.16
Chicago SBM	→ 4	Rotterdam SBM	1.77	1.21	.03
Rotterdam CGF	→ 9	Chicago CGF	10.41*	7.26*	.30
Chicago CGF	→ 9	Rotterdam CGF	1.30	1.69	.09
Rotterdam CGF	→ 1	Chicago SBM	12.74*	6.41*	.04
Chicago SBM	→ 1	Rotterdam CGF	.33	1.03	.01
Chicago Corn	→ 3	Chicago CGF	3.13*	3.96*	.07
Chicago CGF	→ 3	Chicago Corn	.45	.91	.02
Chicago SBM	→ 10	Chicago CGF	5.10*	1.15	.07
Chicago CGF	→ 10	Chicago SBM	1.29	4.30*	.22
Chicago Corn	→ 1	Rotterdam CGF	1.08	1.41	.01
Rotterdam CGF	→ 1	Chicago Corn	.57	.46	.00
Chicago Corn	→ 1	Rotterdam SBM	.82	.46	.00
Rotterdam SBM	→ 1	Chicago Corn	3.62	1.99	.01
Chicago SBM	→ 0[c]	Chicago Corn	no equations		
Rotterdam SBM	→ 0[c]	Rotterdam CGF	no equations		
W. German Barley	→ 0[d]	Rotterdam SBM	no equations		

* Denotes significnace at the five percent level.

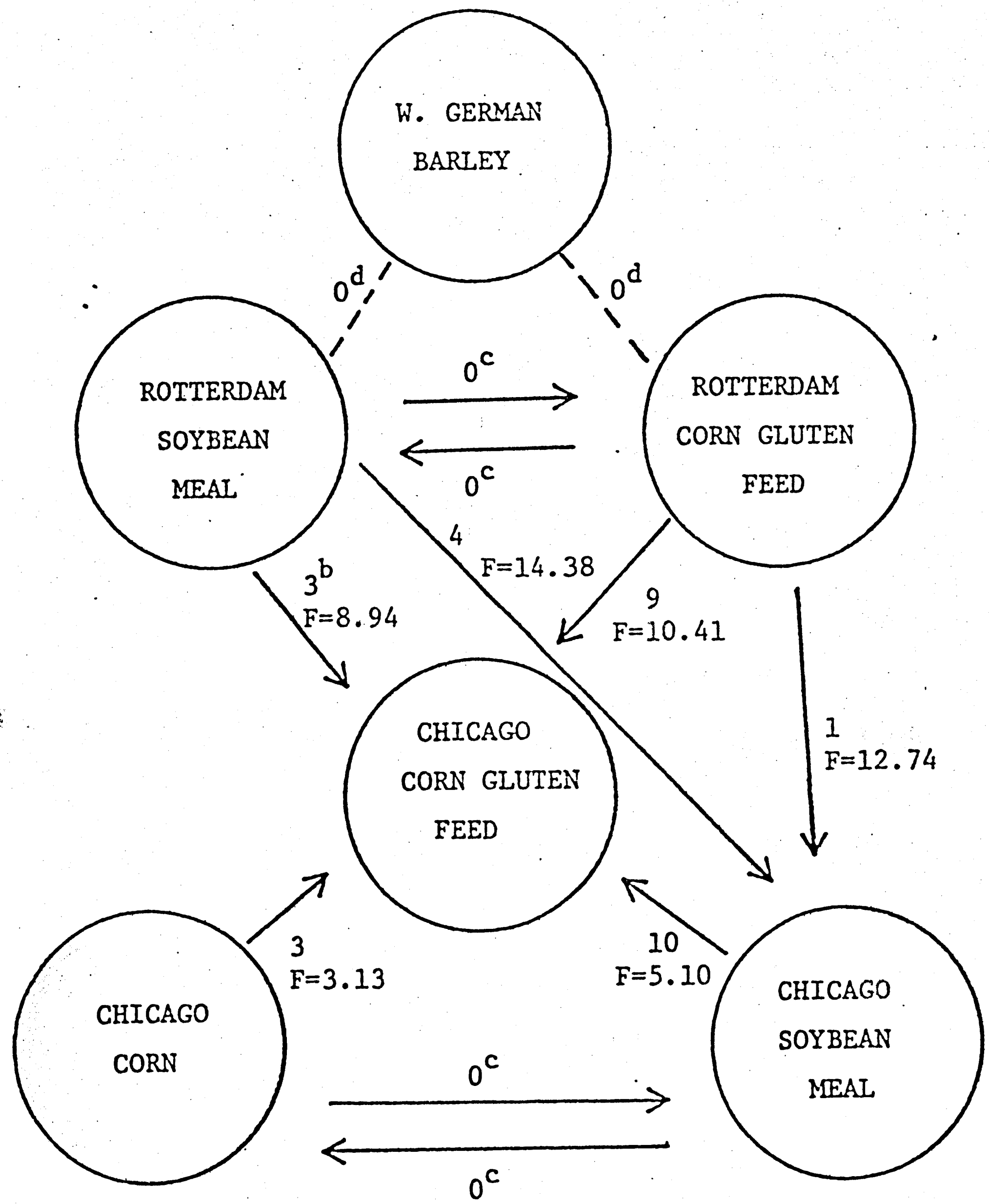
a SBM = soybean meal, CGF = corn gluten feed.

b For example, Rotterdam SBM price leads or "causes" Chicago CGF price by 3 weeks, as evidenced by the significant causality F-statistic.

c Zero represents an instantaneous price discovery, neither market leads nor lags the other, so causality test and equations cannot be utilized.

d Zero represents no relationship between markets, neither market leads nor lags the other, so causality tests and equations cannot be utilized.

Figure 1. Weekly Price Causality Lead-Lag Relationships for Corn Gluten Feed, Soybean Meal, and Corn.[a]



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[a]All causality tests are significant at the five percent level using the Wald F-statistic.

[b]For example, Rotterdam soybean meal price leads Chicago corn gluten feed price by 3 weeks.

[c]Zero represents an instantaneous price discovery relationship.

[d]Zero represents no relationship between markets.

Table 3. Weekly Correlation Coefficients of Price Changes Between Soybean Meal, Corn Gluten Feed, and Corn Markets.

	Rotterdam CGF	Chicago SBM	Chicago CGF	Chicago Corn	W. German Barley
Rotterdam SBM[a]	.45*	.63*	.07	.39*	.15*
Rotterdam CGF		.25*	.18*	.15*	.20*
Chicago SBM			.03*	.61*	.11*
Chicago CGF				.08	.09
Chicago Corn					.09

* Denotes significance at five percent level.

a SBM = soybean meal; CGF = corn gluten feed

Table 4. Long-Run Multipliers for Corn Gluten Feed, Soybean Meal, and Corn.

Commodity		Impact Multiplier	t-value	Prob > |T|	Adjustment Period I	Adjustment Period II
Rotterdam SBM[a]	→ Chicago CGF	.27*	5.57	5.29E-08	6	8
Chicago CGF	→ Rotterdam SBM	-.20	-1.34	.18	5	3
Rotterdam SBM	→ Chicago SBM	.74*	6.30	9.82E-10	5	25
Chicago SBM	→ Rotterdam SBM	-.08	-.93	.35	9	14
Rotterdam CGF	→ Chicago CGF	.86*	7.20	4.41E-12	18	43
Chicago CGF	→ Rotterdam CGF	-.21	-1.56	.12	25	42
Rotterdam CGF	→ Chicago SBM	.39*	3.4	.0007	1	1
Chicago SBM	→ Rotterdam CGF	.02	.56	.58	1	0
Chicago Corn	→ Chicago CGF	.38*	4.05	.00006	6	9
Chicago CGF	→ Chicago Corn	-.10	-1.13	.26	7	6
Chicago SBM	→ Chicago CGF	.32*	5.76	1.99E-08	17	39
Chicago CGF	→ Chicago SBM	-.36*	-2.23	.03	20	47
Chicago Corn	→ Rotterdam CGF	-.09	-1.11	.27	2	0
Rotterdam CGF	→ Chicago Corn	.03	.74	.46	2	0
Chicago Corn	→ Rotterdam SBM	-.14	-.96	.34	1	0
Rotterdam SBM	→ Chicago Corn	.05*	2.09	.04	1	1

* Denotes significnace at the five percent level.

a SBM = soybean meal; CGF = corn gluten feed.