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Cash Price Stability in the Presence of Futures Markets: A Multivariate Causality Test for Live Beef Cattle

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Abstract

Cash Price Stability in the Presence of Futures Markets: A Multivariate Causality Test for Live Beef Cattle

A theoretically motivated, multivariate causality test of the exogeneity of production planning period, term, and forward futures prices in the determination of cash slaughter cattle prices led to the conclusion that these respective futures prices directly affect, have an instantaneous relationship with and have no effect on the cash price in a sample of daily observations.

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Introduction

The impact of futures trading on cash price stability has been an issue of great concern to producers faced with fluctuating cash prices. A series of studies, e.g., Purcell et al. [1979] have considered this issue by attempting to determine the impact of commencement of futures trading on the variance of the random component of cash price series. In all cases, a reduction of variance is found to be coincidental with the initiation of and related to the volume of futures trading. However, this result is largely qualitative and leaves open the question of how futures trading affects the behavior of the cash price. While past theoretical literature has attempted to address this issue, no comprehensive model of futures and cash market price determination has been developed. The objective of this paper is to rely on a theoretical model of cash and futures markets in Weaver and Banerjee [1981] as the basis for an empirical test of the existence of a linkage between cash and futures prices of slaughter cattle.

Cash and Futures Market Behavior and Price Determination

A summary of the demand and supply actions which individual agents can take in cash and futures markets provides a useful basis for a micro-economic model of behavior in these markets. Weaver and Banerjee [1981] present a micro theory of such behavior from which choice functions for optimal hedging, speculation, production and storage are derived. It is demonstrated that in order for futures trading to occur (i.e., for there to exist agents with non-zero hedges and speculative positions) agents either 1) must hold differential information concerning price outcomes, or 2) must have a variety of risk preferences including both risk aversion and neutrality. For this reason, the micro model allows both risk aversion and differential information.

Choice functions for the i^{th} agent based on the micro theory of choice discussed above were employed to specify a model of the cash and futures markets at time t as perceived at t-j. Secondly, the evolution of the markets from t-j to a final convergence at t was presented and employed as a basis for deriving a model of the determination of the final cash price P_t. The model may be summarized as follows:

<u>Cash Market at t-j</u>

1) $$I_{t-j} \equiv \sum_i \sum_{h=-j}^{H} I^i_{t+h,t-j} = I[P_{t-j}, F_{t,t-j}; T(M^i_{t-j}(P_{t-j+1}, \ldots, P_t, \ldots, P_{t+H})), U(X^i_{I,t-j}), V(X^i_{S,t-j}), W(X^i_{Q,t-j})]$$

or in briefer notation,

$$= I(P_{t-j}, F_{t,t-j}; Z_{t-j})$$

2) $$S_{t-j} = \sum_i S^i_{t-j,t-j-m} = S(P_{t-j-m}, F_{t-j,t-j-m}; Z_{t-j-m})$$

3) $$D_{t-j} = D(P_{t-j}, P^S_{t-j}; X_{D,t-j})$$

4) $$I_{t-j-1} = \bar{I}_{t-j-1}$$

5) $$D_{t-j} + I_{t-j} = S_{t-j} + I_{t-j-1}$$

where I indicates inventories,

D_{t-j} is aggregate current consumption demand at t-j,

P^S_{t-j} is a vector of prices of substitute commodities at t-j,

Z_{t-j}, Z_{t-j-m} are appropriately defined vectors of distributions of exogeneous factors,

P indicates cash prices,

F indicates futures price,

$M^i(.)$ is a vector of moments of agent specific, subjective joint probability density functions $g^i(.)$ over future cash prices,

X indicates vectors of exogenous determinants, T(.),U(.),V(.),and W(.) are aggregate summary functions over appropriate sets of agent-specific decision determinants.

Futures Market for t^{th} contract at t-j

Modelling of this market requires introducing additional notation to distinguish hedges from speculative positions. We adopt the following:

6) $Q^+_{t-j} = \sum_{i \varepsilon a} Q^i_{t-j} = Q^+(P_{t-j}, F_{t,t-j}; Z_{t-j})$

7) $Q^-_{t-j} = \sum_{i \varepsilon a'} Q^i_{t-j} = Q^-(P_{t-j}, F_{t,t-j}; Z_{t-j})$

8) $Q^+_{t-j} = Q^-_{t-j}$

where a' is the set of hedgers of the t^{th} contract at t-j

a is the set of speculators on the t^{th} contract at t-j

Q^+_{t-j} is market level supply of the t^{th} contract

Q^-_{t-j} is market level demand for the t^{th} contract.

Cash-Futures Market Equilibrium

The system of equations 1) - 8) are assumed to hold at all points of time between t-j and t and can be solved at time t-j for the cash prices P_{t-j}, namely:

$$9) \qquad P_{t-j} = P(P_{t-j-m}, F_{t-j,t-j-m}, P^S_{t-j}, Z_{t-j-m}, Z_{t-j}, X_{D,t-j}, \bar{I}_{t-j-1}).$$

We assume that market evolution between t-j and t satisfies the following restrictions:

$$\lim_{j \to 0} F_{t,t-j} = P_t,$$

$$g^i_{t-j}(P_t | P_{t-j}, P_{t+1-j}, \ldots P_{t+H}) \xrightarrow{d} P_t \text{ for all i and all values of } P_{t+h}, h \neq 0,$$

$$C_S(S^i_{t,t-j}) = \infty \text{ for all } j > k_s,$$

where k_s represents the minimum production period length;

$\xrightarrow{d}$ means convergence in distribution.

Introducing these restrictions and using 9), the reduced form for P_t can be written:

$$10) \quad P_t = P(P_{t-m}, F_{t,t-m}, P^S_t, Z_{t-m}, Z_t, X_{D,t}, \bar{I}_{t-1})$$

$$\text{where } Z_t = [T(M^i_t(P_{t+1}, \ldots P_{t+H}), U(X_{I,t})]$$

$$Z_{t-m} = [T(M^i_{t-m}(.)), U(X^i_{I,t-m}), V(X^i_{S,t-m}), W(X^i_{Q,t-m})]$$

The effect of storage can be seen as the introduction in the determination of P_t of the exogenous determinants of inventory decisions at t-m, i.e., P_{t-m}, and the subjective distributions of cash prices held by storage agents during the storage period which is feasible following t-m and t. Thus, with storage each cash price P_t is linked to a web of differential subjective distributions concerning future and past cash prices. This result holds regardless of whether a futures market exists. The impact of futures trading on P_t are twofold. First, $F_{t,t-m}$ directly affects P_t and secondly, the subjective probability distributions $g^i{}_{t-m}(P_t)$ held by futures market participants become determinants of P_t. $F_{t,t-m}$ links P_t to past markets and their exogenous factors. In addition to this effect, the existence of futures trade draws into the market new participants whose price conjectures affect P_t. To the extent that these conjectures are based on different beliefs than those held by producers, the behavior of P_t will be indirectly affected by futures trading.

Testing Causality in the Multivariate Case

Recognizing that most economic models are multivariate, Zellner and Palm [1974] and Geweke [1978] extended the Sims [1972] method to the case where several independent stochastic processes cause another stochastic process. The dynamic econometric model can be written in the form

11) $$Y_t = A(L)\ S_t + U_t$$

where: Y_t is the "dependent" time series variable, X_t is a vector of "independent " time series variables, U_t is a stochastic disturbance term independent of X_t that may be assigned a particular structure, and A(L) is a matrix of polynomials of possibly infinite order in non-negative powers of the lag operator L. A(L) has a generating function $A(X) = \sum_{k=0}^{\infty} A_k Z^k$ which is assumed to be convergent for $|Z| \leq 1$. Y_t, X_t, and U_t are posited to have autoregressive representations.

Given the hypothesis that the elements of X_t are jointly strictly exogenous with respect to Y_t, Geweke [1978] has shown that two testable implications may be stated.

Implication A: If only current and past values of X_t are inputs into the determination of Y_t, any conditional projection of Y_t on future, current, and past values of X_t should yield statistically insignificant estimates of the coefficients of the future values of X_t. That is, if we define the regression:

12) $Y_t = B(L)X_t + V_t$

where: X_t and V_t are mutually orthogonal processes and B(L) differs from A(L) only in that it is "two-sided," i.e., includes negative powers of L but has otherwise similar properties of generating functions and convergence.

By implication A, the elements of X_t are exogenous relative to (i.e. cause) Y_t if the coefficients of futures values of X_t implicit in B(L) are zero.

Implication B: If X_t is truly exogenous with respect to Y_t, the evolution of X_t over time should not be affected by Y_t. Therefore, in a regression of X_t

on its own past values and on the past values of Y_t, all coefficients of the lagged Y's should be statistically insignificant. Define this regression:

$$13)\quad X_t = C(L)\, X_t + D(L)\, Y_t + W_t$$

where C(L) and D(L) are matrices of polynomials in strictly positive powers of L.

The generating functions of both are assumed to satisfy the required convergence properties. Assume W_t is a serially uncorrelated, zero mean process, independent of X_t and Y_t. Then in this mixed distribution lag regression, X_t is truly exogenous to Y_t if all coefficients in D(L) are zero.

The estimation procedure for testing the two implications should account for the following possibilities: (a) in distributed lag regression using time series, the regressors are likely not to be independent of the disturbance term and (b) the population disturbances are likely to follow very general time series processes. The Hannan inefficient frequency domain method is desirable for estimation of 27) and 28), see Weaver and Banerjee [1981] for details. They provide asymptotically efficient and consistent estimates under perfectly general patterns of serial correlation in the disturbance process and, because they are based on Fourier methods, they also yield mutually orthogonal coefficient estimates in distributed lag regressions which permits addition or deletion of variables in distributed lag regressions without re-estimation.

An Application to Live Beef Cattle

The cash cattle market is a good example of trading in an almost nonstorable commodity. Long-term inventories such as between times t-m and t (corresponding to the production planning and the marketing periods respectively in our theoretical model) may be virtually impossible to hold, particularly if the "production" or feeding period m is, as we assume for our study, as long as six months. This means that the cash price P_{t-m} when production commences (which, as our model shows, is used in planning such inventories) may have a negligible impact, if any, on the cash price P_t at marketing . Similarly, long-term inventories of fed marketable cattle beyond time t may also be doubtful. The possibility that medium-term inventories may exist beyond time t (say, until time s where s is two months) may be adequately accounted for by hypothesizing that the price at t for the next tradable futures contract, $F_{t+s,t}$, is contained in the information set Ω_t as an indicator of P_{t+s}, the expected cash price for s at t.

In relating this discussion to our cash price reduced form in equation 10), note that the role of P_{t-m} in the function P(.) has been ruled out. Other exogenous determinants of P_t in equation 10) include Z_t and Z_{t-m}. An element of Z_t is the distribution of the vector of moments $T(M^i{}_t(P|\Omega_t))$ where P is a vector of prices. These moments are conditional upon information available at t, namely Ω_t. Hypothesizing that futures trading influences Ω_t, it can be argued that $F_{t,t}$ and $F_{t+s,t}$ are important elements of Ω_t. This makes Z_t, and indirectly P_t, functions of $F_{t,t}$ and $F_{t+s,t}$. Further, by a similar hypothesis, Z_{t-m} include the costs of supply (accounted for by the prices of variable inputs), costs of futures transactions and the costs of inventories (which may be negligible as argued above).

In sum, given that equation 10) is the appropriate reduced form for cash prices of slaughter cattle, our primary interest is in testing the hypothesis that P_t is a function of two futures prices $F_{t,t}$ and $F_{t+s,t}$ which are expected to reflect the information set upon which agents base their different choices. P_t is also a function of the prices of substitute commodities and prices of variable inputs. Finally, P_t is a function of demand-side factors (incomes, tastes), production technologies and the costs of futures transactions and storage.

A suitable empirical specification of the cash price reduced form would be:

$$14)\quad \left(\frac{PSC}{PSH}\right)_t = P\left[\left(\frac{PDB}{PSH}\right)_t, \left(\frac{FLC2}{PSH}\right)_t, \left(\frac{FLC3}{PSH}\right)_t, \left(\frac{FLC1}{PCI}\right)_{t-m}, \left(\frac{PFC}{PCI}\right)_{t-m}, \left(\frac{PSMI}{PCI}\right)_{t-m}\right]$$

where all variables are prices, namely, PSC (slaughter cattle), PSH (slaughter hogs), PDB (dressed broilers), PFC (feeder cattle), PSMI (soybean meal), PCI (corn), FLC1("past" futures price of live beef cattle, corresponding to $F_{t,t-m}$ in our theoretical model), FLC2 ("term" futures price of cattle, corresopnding to $F_{t,t}$), and FLC3 ("forward" futures price of cattle, corresponding to $F_{t+s,t}$). Note that equation 14) is expressed in relative prices, a consequence of imposing linear homogeneity on the cash price reduced form. A fuller specification to include other exogenous variables in P(.) is not adopted because of the relatively short sampling period of daily observations, during which variation in the excluded variables may have in fact been small and inconsequential. All price data are taken from readily accessible sources, namely, the Wall Street Journal, the Chicago Board of Trade Statistical Annual, and the Chicago Mercantile Exchange Annual Yearbook. The sampling periods are

August 1977 to December 1979 for PSC, PSH, PDB, FLC2, and FLC3, and February 1977 to June 1979 for PFC, FLC1, PCI and PSMI. Each sample contains 513 obervations. All subsequent statistical work is based on the empirical specification in equation 14).

To test whether the functional relationship in 14) is also a "causal" relationship, we adopted the Sims-Geweke procedure. To test Implications A and B it was desirable to require that the time series variables in 14) be jointly covariance stationary, possibly possessing an autoregressive representation. It was found that each series was nonstationary in levels but stationary on the first difference. Further, all except the relative prices of feeder cattle and of soybean meal were found to possess autoregressive structures. In all subsequent testing, therefore, we worked only with the differenced series since they were jointly covariance stationary.

In testing Implication A, the lags and leads on the right-hand-side variables were restricted following the Amemiya and Fuller [1967] rule to 8 lags and 8 leads. The dependent variable in both tests was the relative price of cash cattle hypothesized to be endogenous. The HI estimation results for the test of Implication A are reported in Weaver and Banerjee [1981]. While cash broilers price had a significant coefficient at the zero lag, term futures cattle price had a significant coefficient at the zero and the third lag. There were no significant coefficients from forward futures cattle price. The same was true of cash soybean meal price. While past futures cattle price and cash feeder cattle price had some significant lead coefficients, such a finding could only be interpreted as a statistical artifact probably indicating that the actual production process is about a week or so less than the approximately 180 days hypothesized in our analysis. In sum, none of the contemporaneous time series specified to be exogenous were found to receive any feedback (as would be apparent from significant coefficients of leads) from the time series specified to be endogenous. Implication A of the hypothesis of exogeneity (causality) was thus validated.

To test Implication B the following regressions were employed:

$$15) \quad X_{it} = \sum_{i=1}^{6} \sum_{j=1}^{p} c_{ij} X_{i,t-j} + \sum_{k=1}^{q} d_k Y_{t-k} + W_{it}$$

for all i, where the range of i represents the six time series specified to be exogenous, p and q are finite, and Y is the hypothesized endogenous time series. Under the hypothesis that W_{it} is serially uncorrelated and contemporaneously uncorrelated with the right-hand-side variables, OLS estimates of c_{ij} and d_k should be consistent and asymptotically efficient if p and q are made to depend on sample size T. 15) can be viewed as a six-equation system of regressions where in each equation the X_{it} on the left-hand-side corresponds to one of the six time series specified to be exogenous. Since 15) represents a system of seemingly unrelated regressions, and each regression has a common set of regressors, 3SLS estimation of 15) amounts to OLS estimation of each individual regression. To get the 3SLS (equivalently, OLS) estimates, we set p = q = 8.

Results indicated that in the case of two of the three contemporaneous variables (viz., the cash broilers price and the forward futures cattle price) there were no significant coefficients at any lag of Y. However, in the regression for term futures cattle price, the coefficient at the second lag of Y was about three times its standard error. On the face of it, this finding suggested a two-day feedback effect from the cash cattle price to the term futures cattle price. This prompted a second round of testing in which 15) was re-estimated under the null hypothesis that all d_k in each regression were jointly zero. We then used four different test statistics to test this null hypothesis, i.e., to determine whether the restricted model (with all d_k set to zero) was equivalent to the unresticted model (with d_k unrestricted).

The four test statistics used for this purpose were the conventional F-test, the Wald statistic, the Likelihood Ratio statistic, and the Lagrange Multiplier statistic. Results of these tests indicate that the null hypothesis (all $d_k = 0$ jointly, in each regression) cannot be rejected at any reasonable significance level for any of the contemporaneous X_i. On the basis of these tests, we therefore conclude that the hypothesis that all three contemporaneous time series are exogenous with respect to the time series specified to be endogenous cannot be rejected. This inference from the test of Implication B is entirely supportive of the inferences drawn from the test of Implication A. A summary of the exogeneity test results are reported in Table 1.

We conclude that tests of Implication A and B provide support for the hypothesis that futures trading of slaughter cattle has two effects on cash price dtermination. First, a direct effect is apparent through the role of $F_{t,t-m}$, the planning period value of the t^{th} contract, in the formation of subjective price forecasts for time t and the resultant effect of these forecasts on production decisions. Secondly, the finding that $F_{t,t}$, the term futures, was not temporally exogenous with respect to P_t suggests that no direct non-instantaneous effect of $F_{t,t}$ on P_t exists. However, the significance of $F_{t,t}$ in explaining P_t suggests that there exists an instantaneous relation between the two prices. This instantaneous effect may be either direct or indirect and will be the subject of future research. It should be noted that this study represents the first attempt at establishing the types of causal relationships that exist between cash and futures market prices within the context of a multivariate market model derived from a micro economic theory of cash-futures market linkages. We are aware of only one other study, namely that by Purcell et al. [1979], which addresses the question of causality between cash and futures market prices. That analysis, however, employs only a bivariate model.

Table 1 Summary of Exogeneity Test Results*

Variable	Variable Type	Result
Cash Broilers price ($\frac{PDB}{PSH}$)	Current	Exogenous but also instantaneously related
Term Futures Cattle price ($\frac{FLC2}{PSH}$)	Current	Exogenous but also instantaneously related
Forward Futures Cattle price ($\frac{FLC3}{PSH}$)	Current	Absence of any relationship
Past Futures Cattle price ($\frac{FLC1}{PCI}$)	Past	Exogenous
Cash Feeder Cattle price ($\frac{PFC}{PCI}$)	Past	Exogenous
Cash Soybean Meal price ($\frac{PSMI}{PCI}$)	Past	Absence of any relationship

Note

* The null hypothesis is that the prices $\frac{PDB}{PSH}$, $\frac{FLC2}{PSH}$, $\frac{FLC3}{PSH}$, $\frac{FLC1}{PCI}$, $\frac{PFC}{PCI}$, and $\frac{PSMI}{PCI}$ are all jointly exogenous with respect to the Cash Slaughter Cattle price $\frac{PSC}{PSH}$ which is a current variable.

References

Amemiya, T., and W. A. Fuller, "A Comparative Study of Alternative Estimators in a Distributed Lag Model," Econometrica, 3,4 (July-Oct., 1967): 503-529.

Geweke, J., "Testing the Exogeneity Specification in the Complete Dynamic Simultaneous Equation Model," Journal of Econometrics, 7,2 (April 1978): 163-185.

Purcell, W. D., D. Flood, and J. S. Plaxico, "Cash Futures Interrelationships in Live Cattle: Causality, Variability, and Pricing Processes" in R. M. Leuthold and P. Dixon (eds.). Proceedings from the First Annual Livestock Futures Research Symposium, Chicago, (June 1979).

Weaver R.D. and A. Banerjee, "Cash Price Stability in the Presence Futures Markets: A Multivariate Causality Test for Live Beef Cattle", Staff Paper #45, Department of Agricultural Economics, Pennsylvania State University, July 1981.

Zellner, A. and F. Palm, "Time Series Analysis and Simultaneous Equation Econometric Models," Journal of Econometrics, 2, 1 (May 1974):17-54.