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IMPULSE RESPONSE AND INTERTEMPORAL PRICING OF COTTON

Dean T. Chen and David A. Bessler*

I. INTRODUCTION

Structural econometric models are often used for impact simulation analysis of policy shocks. However, they have not been well adapted for futures market research. Considerable controversy exists over the behavioral hypotheses of spot and futures price equilibrium, particularly their interactions under conditions of policy shocks and exogenous disturbances. In view of the lack of well-accepted intertemporal pricing theory and well-adapted models, this study explores a less restrictive technique of vector autoregression, which has been previously adopted for policy impact analysis (see for example, Burbridge and Harrison). In the design of the impulse response study, we take an initial step of incorporating a simple structural model specification of conditional market expectations in derivation of reduced form equations.

Previous econometric modeling efforts suggest that inventory stocks play a dominant role in intertemporal pricing of storable agricultural commodities with active futures markets. Based upon Working's storage theory, the price spread or the basis can properly be viewed as the market determined price of storage (Working, 1949). As such, it sets a simple equality condition for the basis to equal the marginal costs of storage where current stocks become a crucial connecting link between the spot and futures markets. This conceptual framework has provided the foundation for numerous empirical studies of intertemporal price relationships for several agricultural commodities, for example, the work on corn, soybeans and potatoes (Tomek and Gray) and a more recent study of soybeans (Lowry, Glauber, Miranda and Helmberger).

Due to its restriction on the stochastic interactions of the spot and futures prices, Working's formulation has been criticized as an unrealistic representation of commodity price dynamics. Weymar suggested that price spread between futures contracts of two different delivery dates should depend upon expected stocks rather than stocks already in existence. Several other theoretical arguments that have been explored in the literature have also complicated model specification issues, notably the work on interest rate parity (Frankel, Gordon), risk premium (Gray, Dusak, Hauser and Anderson), and convenience yields (Working, 1948; Brennan).

This paper also seeks to broaden our understanding of the interactions between spot and futures prices by considering an unusual period of price movement in the cotton market caused by policy shocks of the marketing loan program in 1985 and 1986. Differential impacts of pricing dynamics are examined by impulse response analysis for spot and futures markets in periods before and after the policy implementation. Impulse responses and historical error decompositions are computed to determine the time path of price adjustments to policy shocks in three different time periods. These VARs are converted to their moving-average representations, and Sims's innovation-accounting techniques are used to examine the impact of policy shocks on commodity price changes. The study provides useful insights into intertemporal pricing theory, in particular, the stochastic, dynamic, simultaneous and general equilibrium properties of price determination in the spot and futures markets.

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The paper begins with a review of the structural model specification of intertemporal pricing of storable agricultural commodities -- the behavioral relationship of the basis and inventory stocks and the role of conditional market expectations. Special references are made with regard to key theoretical issues in the specification of intertemporal market equilibrium for econometric analysis. In the third section of this paper the policy simulation problem is reformulated into a vector autoregressive context for testing impulse response hypotheses. The innovation-accounting techniques are used to test the effects of policy shocks on spot and futures price in Memphis, Liverpool and New York futures markets. The results of impulse responses and causality tests are presented in section 4, followed by concluding remarks in section 5.

II. STRUCTURAL MODEL SPECIFICATION

To help demonstrate various specification issues in modeling intertemporal price relationships, this paper utilizes a simple structural model framework within which various theoretical approaches can be described and compared. Working's theory and the related literature indicate that two major functions of the futures markets are inventory adjustment and price expectations. A key assumption underlying Working's specification is that the price determination process in the futures market can be separated into two components: the effects of inventory stocks and storage costs on the inter-period price differences, and the effects of market expectations (forecast) on the overall level of cash and futures prices.

Based upon Working's costs of storage theory and the subsequent modifications, the intertemporal price relationship can simply be stated by a system of two equations:

$$F_{t,t+k} - P_t = ic + sc - cy + u_1 \quad (1)$$

$$\text{where } F_{t,t+k} = E[(P_{t,t+k}) / I_{t,t+k}] - rp + u_2 \quad (2)$$

$F_{t,t+k}$ = Futures price at time t for contract delivery $t+k$ periods ahead,

P_t = Current spot market price at time t ,

ic = Interest cost,

sc = Storage cost,

rp = Risk premium,

cy = Convenience yield,

$E(P_{t,t+k})$ = Expected spot price for period $t+k$ conditional on information available at time t ,

$I_{t,t+k}$ = Market information available at time t for formulating conditional expectations of spot market price $t+k$ period ahead,

u_1 , and u_2 = Disturbance terms in equation (1) and (2) respectively

Equation (1) describes the traditional arbitrage argument in determination of the intertemporal price spread or basis relationship. Equation (2) is a simple specification of the conditional expectation hypothesis and the role of futures price as an expectation of the future spot price.

Intertemporal Price Spread

As shown by the first two RHS variables of equation (1) the basis is determined by the actual and opportunity costs of storage for the interval of time through contract maturity date (k periods), consisting of the rental cost of physical facilities in which the commodity is stored, sc ; and the interest cost on invested capital, ic . This is an equality condition underlying Working's storage theory. Since values of these two cost items are generally known in advance, they are exogenous in the model. Based on this formulation, Working's theory is thus a static, deterministic and partial analysis framework.

It is a well known fact that this equality condition does not hold because the price spread frequently turns out to be negative. To explain this "inverse carrying charge", the concept of convenience yield was introduced. Convenience yield is commonly defined as the difference between the spot price plus interest plus physical storage costs and the futures price. Conceptually, it describes the inventory holding behavior in maintaining stocks for transactions purposes. Convenience yield is entered as a negative argument in calculating net costs of storage based on an inverse relationship with levels of current stocks (Brennan) or the expected stocks (Weymar). This specification is most conveniently used to explain the conditions of negative basis when the futures price is below the spot price.

The convenience yield actually cannot be determined as *a priori* since it depends upon, among other things, current or expected levels of stocks. With the introduction of convenience yield, equation (1) contains a stochastic term but is still a static formulation. Considerable confusion exists over the theoretical explanations of convenience yield because it fails to distinguish its role in inventory adjustment and market expectations. Although it is useful to explain all those factors which may cause the basis to fall below the interest rate and storage costs, the model does not offer satisfactory results on both theoretical and empirical grounds. Gordon proposed to develop a separate equation by explicitly entering the convenience yield as a function of interest rate, expected supply and demand, and current inventory of the commodity. However, there is little theoretical justification or empirical evidence to support such a specification.

Conditional Expectations

The role of expectations is the heart of specification issues in intertemporal pricing theory. A simple formulation of the conditional expectation hypothesis is presented in Equation (2) which shows the futures price ($F_{t,t+k}$) as a function of the expected spot price ($E(P_{t,t+k})$) conditional on market information ($I_{t,t+k}$) currently available. A risk premium (rp) is formally incorporated in the model to reflect uncertainty and risk aversion of market participants.

A major limitation of intertemporal price theory is the absence of a satisfactory framework for formulating market expectations. To properly conceptualize and measure the effects of expectations on futures market, Just and Rauser suggest that an internally consistent dynamic representation of market expectations is needed. The challenge is to incorporate expectations into equation (2) in determining of the

futures price conditional on current set of market information. Considerable controversy exists over the specification of the conditional expectation hypothesis in intertemporal analysis. Much of the difficulties arises from empirical measurement, regarding the tractable dynamic representation of information flow in expectations formation.

Key Theoretical Issues

The lack of success of traditional approaches in modeling intertemporal pricing relationships may be attributed to their failure to give full consideration to the stochastic interactions of the arbitrage condition and market expectations. An integration of this two-equation system may yield additional insights on intertemporal pricing theory. First, the modeling of the arbitrage condition is subject to the constraints of market expectations, and secondly, a dynamic representation of market expectations must rely upon a comprehensive set of market clearing forces at play in both spot and futures markets.

Through simple substitution of equation (2) into equation (1), a reduced form equation for expected future spot price can be derived as:

$$E[(P_{t,t+k}) / I_{t,t+k}] = P_t + ic + sc - cy + rp + u_3 \quad (3)$$

where, $u_3 = u_1 - u_2$ is a random disturbance term with zero mean and finite variance. It is also assumed that the disturbance terms in (1) and (2) are random with zero mean, $E(u_1) = 0$, $E(u_2) = 0$ while the covariance between u_1 and u_2 is also zero, $Cov(u_1, u_2) = 0$. In equation (3), the expected future spot price, expressed in the expectation term and conditional on a set of current market information for $t+k$ periods ahead, is a function of current spot price plus interest charge, storage cost, risk premium and minus the convenience yield. Note that the convenience yield here is defined in the strong sense, reflecting the transactional convenience of stocks holder, not as a loose term commonly used in the literature.

This formulation is useful to clarify several theoretical issues involved in spot and futures price analysis. Special attention is directed to the **stochastic, dynamic, simultaneous, and general equilibrium** properties of intertemporal pricing theory in spot and futures price determination.

Much has been done over the years to modify Working's **deterministic** framework into a **stochastic** framework. Equations (1) and (2) clearly demonstrate the advantage of this stochastic property. Here we may question the validity of the convenience yield argument, but the model is a more realistic formulation than its original specification.

This simple two-equation specification may also be used to demonstrate the **dynamic** property of the model. In a forecasting situation, on an *ex ante* basis, the current spot price in equation (1) may be determined by a system of simultaneous equations emphasizing the dynamic time path of price determination.

The **simultaneous** nature of spot and futures price determination has received considerable attention in the literature (Stein, Turnovsky). It is important to consider spot and futures price determination as a simultaneous process with full feedback relationships between spot price, futures price and conditional market expectations. By doing so, the P_t in equation (1) should be treated as an endogenous variable which itself may be determined by a system of equations.

The importance of **general equilibrium** analysis on the commodity markets needs particularly to be stressed in view of the increasing interdependency of agricultural markets with domestic and international economies. A serious omission of Working's storage theory is the effects of external disturbances generated from policy shocks and other exogenous changes in both the domestic and international areas.

It is useful to use this two-equation system specification to clarify several other issues involved in specifying intertemporal pricing relationships.

- Equation (3) clearly demonstrates the futures price is not an unbiased forecast of future spot price because of the existence of systematic bias components of interest rate, storage costs, risk premium, convenience yield and others embedded in the intertemporal price relationships.
- By endogenizing P_t , which is determined by a system of simultaneous equations, information concerning future supply-demand conditions and expected stocks should influence current period spot prices. Based on conditional expectation formulation, a comprehensive set of market expectation information is assumed to influence spot price determination. This specification supports some previous studies, particularly Pearson and Houck.
- There are differential price impacts on spot and futures markets in response to external disturbances generated by policy shocks and changes in exogenous variables. In evaluating the impact of external shocks the conditional expectation framework is particularly useful in search of the transmission mechanisms and simulation instruments.

III. IMPULSE RESPONSE HYPOTHESES

The structural model framework presented in the previous section assumes that the price determination process for a storable agricultural commodity with active futures markets is one which produces for any point in time with a given market information set, two simultaneously determined price outcomes -- a current period market clearing spot price and a current period market clearing price of futures contracts. Thus the theoretical framework for a fully simultaneous and dynamic price determination process must reflect the behavior of two interrelated markets: (1) the market for spot price determination given the interactions of supply, demand, stocks and other market-clearing forces and (2) the market for future price determination given market information on future supply, demand, and stocks, in relation to current spot market price, interest rate, storage charge, risk premium, and convenience yield. The link between these two markets is embedded in a fully stochastic, dynamic, simultaneous and general equilibrium framework within which spot and futures prices are determined.

The 1985 and 1986 cotton price experience under conditions of a government policy shock is studied using VAR and impulse response analysis. This unusual period of price movement covers about 18 months. A 12 months period prior to the policy shock began in August 1985 and ended in July 1986, while the six months immediately after August 1986 represented the policy impact period. Throughout the timespan, the Liverpool "A" Index dropped from 57 cents per pound in August 1985 to 37 cents per pound in July a year later, and rose to around 60 cents in December 1986. In contrast, the U.S. Memphis price increased from 57 cents in August 1985 to 65.5 cents in July 1986, dropped 39 cents to the world price level in August, and then climbed up to about 52 cents by December 1986.

Due to the price support program, U.S. cotton prices held well above world prices by 20-30 cents per pound with little fluctuation before the marketing loan program. In August 1985, the December 1986 futures began dropping from 58 cents per pound to a low point of 30.5 in July a year later, and recovered strongly to a high of 54.4 per pound before the December expiration date. The effect of the marketing loan program is particularly visible for the month of August 1986, when Memphis spot price registered a record drop of 39 cents per pound from the July average of 66 cents to 27 cents. The impacts of policy shock on spot and futures price movement can be found in Chen and Anderson (1987).

Based on this price experience, behavioral hypotheses underlying this policy shock are summarized as follows:

Note from equation (1) and (2) that shocks originating in our futures price-expectation equation (2) will feed into our futures price - spot price equation (1). Thus expectations of future spot price may affect spot price. Going the other way, shocks originating in the spot price - futures price equation (1) will feed into the futures price - expectation equation (2); again, it is the futures price which makes this link. Thus we would expect to see futures price leading cash prices under some particular information shocks and cash prices leading futures under others.

If we represent futures prices at time period t by $F_{t,t+K}$ and spot price by P_t , a moving average representation of the vector $(F_{t,t+K}; P_t)$ will be given as the vector equation number (4).

$$X_t = A_1 E_1 + A_2 E_2 + \dots + A_n E_n + A_0 E_0 \quad (4)$$

where, A_i is a 2×2 moving average parameter matrix at time t in the lag $i = 0, \dots, n$, X_t is a 2×1 vector of futures and spot prices, and E_i is a 2×1 vector of information shocks. In the long form, equation (4) is written as:

$$\begin{vmatrix} F_{t,t+k} \\ P_t \end{vmatrix} = \begin{vmatrix} A_{11}(1) & A_{12}(1) \\ A_{21}(1) & A_{22}(1) \end{vmatrix} \begin{vmatrix} e_1(t-1) \\ e_2(t-1) \end{vmatrix} + \dots + \begin{vmatrix} A_{11}(n) & A_{12}(n) \\ A_{21}(n) & A_{22}(n) \end{vmatrix} \begin{vmatrix} e_1(t-n) \\ e_2(t-n) \end{vmatrix} + \begin{vmatrix} e_1(t) \\ e_2(t) \end{vmatrix} \dots\dots\dots(4)$$

Here current futures prices and current spot price are represented by past shocks in futures $[e_1(t-n)]$ and spot prices $[e_2(t-n)]$. By ordering the contemporaneous covariance matrix we can consider shocks in either the spot or futures market and their dynamic impacts across each market. That is, we can consider shocks originating in either the cash or futures market and how they affect futures and cash prices over time. Below we consider such shocks for both pre- and post policy change data.

IV. EMPIRICAL RESULTS

Relationships among daily world and domestic cash cotton prices and daily December cotton futures prices were studied in a vector autoregression. Spot market prices for Memphis and Liverpool data were obtained from Weekly Cotton Market Review published by Agricultural Marketing Service, USDA. Futures prices represent daily closing price at the New York Cotton Exchange; Memphis cotton prices are spot market prices for fiber length 1 1/16 and world prices are represented by C.I.F. Northern Europe price 'A' Index furnished by Cotton Outlook of Liverpool, England.

Results are presented for three time periods - the 1985 contract, the 1986 contract prior to August 1, 1986 and the 1986 contract after August 1, 1986. Of course, we focus on these three periods because of the 1986 shock in U.S. cotton policy. The policy actually took affect in August of 1986 but it was announced and certainly would have impact on agents' expectations prior to August 1986. A separate vector autoregression (VAR) is estimated for each of the three time periods. Each VAR is a three element model. Particular zero restrictions are put on the elements of the autoregressive parameter matrices through the application of the Final Prediction Error (FPE) criterion; following the procedure suggested by Hsiao (1979). Final estimated models were from seemingly unrelated regressions supplied to the levels of each series.

Table 1 summarizes the models identified by the FPE search procedure for each time period. Notice that there is considerable interaction among the three series. Interestingly though, is the difference between the model which generates futures prices in 1985 versus those that generate futures prices in both 1986 periods. The

Table 1. Model Summaries on lagged variables in each VAR model.

	<u>World price</u>				<u>Memphis</u>				<u>Futures</u>			
					(1985)							
<u>Equation</u>	-1	-2	-3	-4	-1	-2	-3	-4	-1	-2	-3	-4
World price	x				x	x	x		x	x		
Memphis	x				x	x	x	x	x	x		
Futures									x	x	x	x
(1986, prior to August 1)												
World price	x	x	x	x	x				x	x		
Memphis	x				x				x	x	x	
Futures					x	x	x		x			
(1986, after August 1)												
World price	x	x	x	x	x				x	x		
Memphis	x				x				x	x	x	
Futures					x	x	x		x			

1985 model of futures prices is a four lag univariate autoregression; while both 1986 models have lagged Memphis prices in the futures representation. In other words, the Memphis price Granger - causes futures prices over the latter two time periods, while it does not over the early period. In addition, futures prices Granger - cause world and Memphis prices over both time periods.

The dynamic interactions embedded in three autoregressions are summarized by the impulse response functions (Sims 1980) given in figures 1, 2, 3, and 4. The responses are derived under an ordering of contemporaneous innovation covariance which puts world price first, followed in order by futures price and Memphis price.

Figure 1 gives the response of Liverpool spot price to the futures price over the three relevant time periods -- 1985, 1986 pre-August and 1986 post-August. Note that the response after the policy shock is much different than both of the 1985 and pre-August 1986 models. That is the world price responded much quicker to an information shock in the futures market after August 1986 than it did before August 1986.

Figure 2 gives the futures response to a shock in the Liverpool (world price) over all three periods. Note that there is virtually no response in the 1985 period, while over the 1986 period there are two distinct response patterns. First, on data observed prior to August 1, there is an initial increase in futures prices due to a one unit increase in world price, this increase persists for several periods, but is followed eventually by a strong decline. This strong and steady decline perhaps indicates an unstable response pattern in the 1986 futures market prior to August 1, 1986. On the other hand, the response of future prices to a shock in world price after August 1 is both strong, positive and stable.

A similar response pattern is seen in figure 3. Here we give the response of futures prices to innovations in the Memphis spot price. Again, there is no response in futures prices over the 1985 contract, a strong negative (although now stable) response over the pre-August 1, 1986 period, and a strong, positive and stable response over the post-August 1, 1986 period.

From figures 2 and 3, we suggest that the government program insulated futures prices from world and Memphis price innovations over the 1985 period. While after the August 1, 1986 new program, futures prices respond quite freely to innovations in the world and Memphis price. Our innovation response plots suggest a more interesting (perhaps non-stable) response during the pre-August 1986 period for December 1986 futures.

These responses are consistent with the pattern which emerges from analysis of forecast innovation decompositions (Sims 1980). Table 2 presents the partitions at horizons of 0, 1, 3 and 10 day horizons. Over the 1985 period futures prices account for all of their error variances at all four horizons. Over the pre-August 1986 period, futures accounts for most of its own error variance, although now there is a trace of error variance attributable to the Memphis price innovations. Finally, over the post-August 1986 period, there is considerable explanation attributed to both world price and Memphis price innovations - especially at the 10 day forecast horizon.

A similar pattern of differential responses emerges in analysis of Memphis prices. Figure 4 gives the response of the Memphis price series to 1985, pre-August 1, 1986 and post-August 1, 1986 innovations in futures prices. In the 1985 period, the Memphis price does respond to shocks in the futures price; however, the response is short-lived lasting for about 1 week. Over the 1986 period, the responses are quite different from

Figure 1

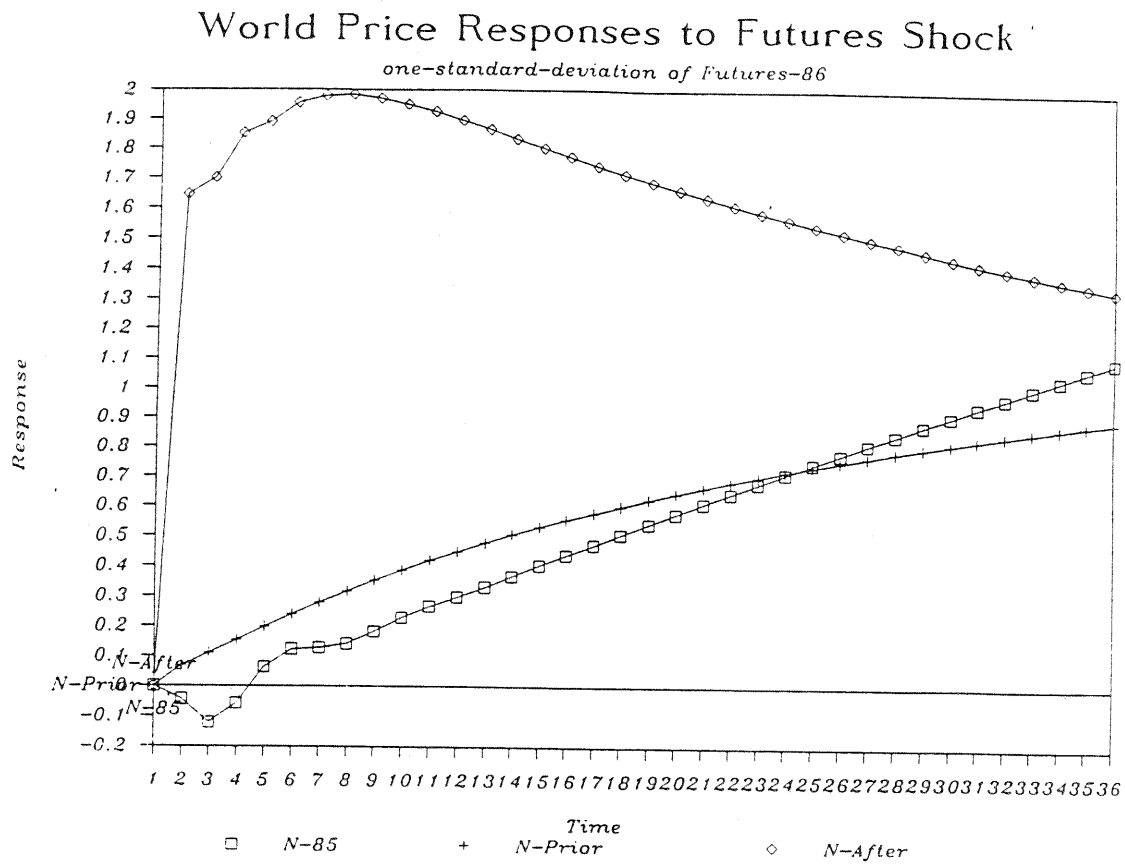


Figure 2

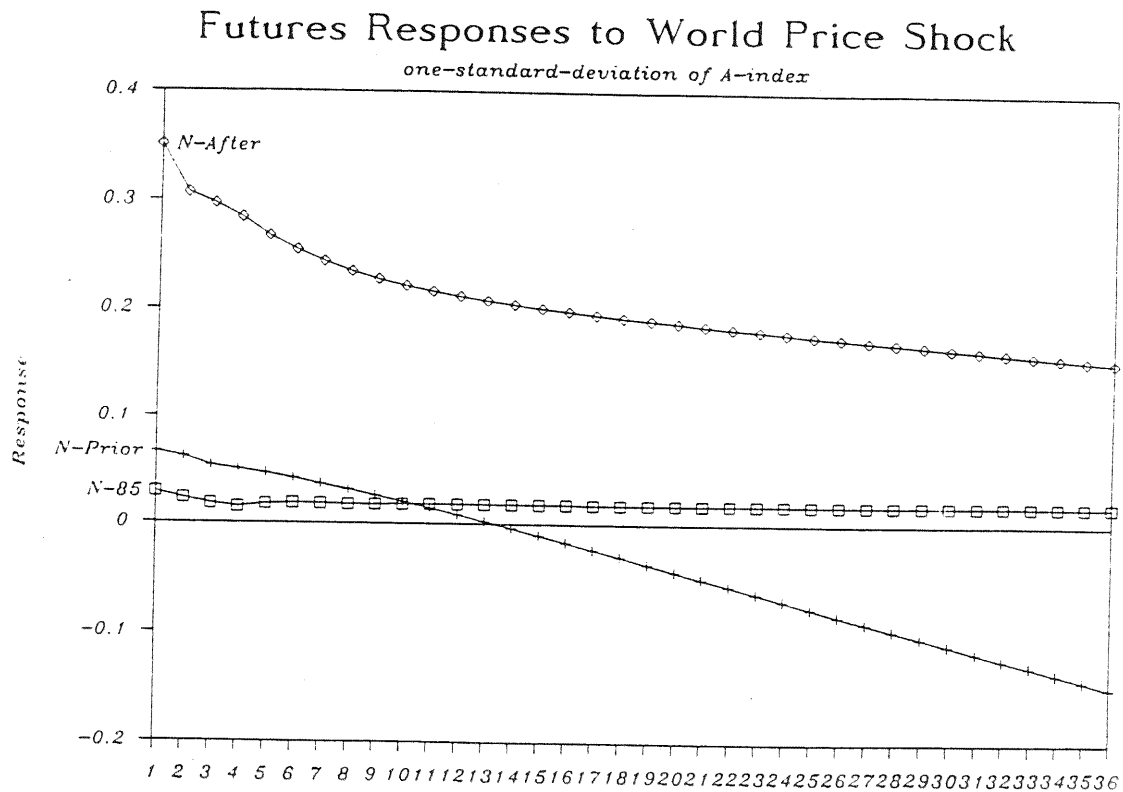


Figure 3

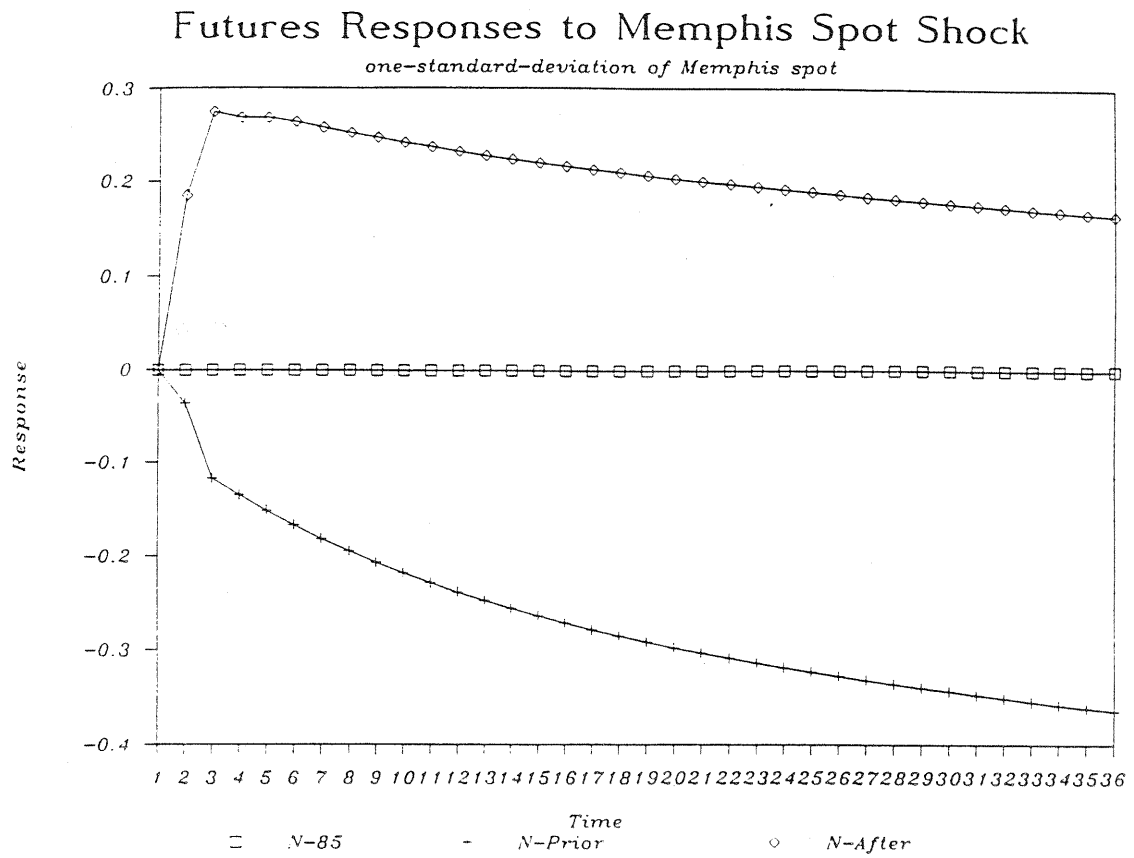
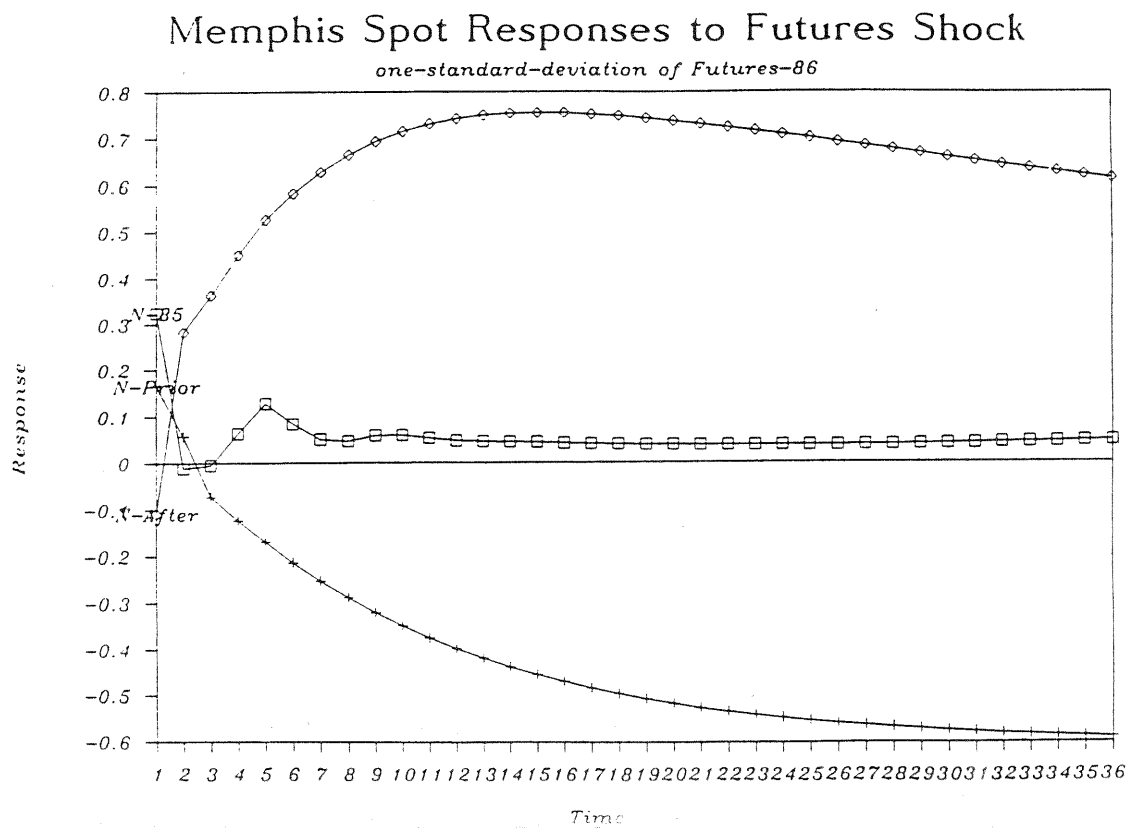


Figure 4



one another. Prior to the August 1 date, a strong negative pattern emerges (a positive shock in futures prices results in still lower Memphis prices). After August 1 the pattern is strong and positive (although an initial (period zero) negative response is noted).

The differential response pattern of Memphis prices pre-and post-August 1, 1986 to shocks in futures prices is interesting and worth further discussion. An information shock (positive innovation) in the futures market price prior to August 1, 1986 apparently resulted in lower cash price. Perhaps, this indicates that less cotton was being released from storage into the cash market, in anticipation of higher spot prices in the future. Holders of cotton inventories were perhaps using the futures price as an expectation generating mechanism. This negative pattern is reversed in the post-August 1 period. Here a positive innovation in futures price leads to a corresponding positive response in the Memphis cash price (after the initial counter intuitive negative response).

Table 2 Decomposition of Within-Sample Innovation Variance on Futures Prices by Series and Horizon.

	<u>World price</u>	<u>Futures price</u>	<u>Memphis</u>
(1985)			
horizon			
0	.00	1.00	.00
1	.00	1.00	.00
3	.00	1.00	.00
10	.00	1.00	.00
(1986, prior to August 1)			
0	.00	1.00	.00
1	.00	1.00	.00
3	.00	.99	.01
10	.00	.97	.03
(1986, after August 1)			
0	.12	.88	.00
1	.12	.85	.02
3	.13	.80	.07
10	.15	.73	.12

A similar story on Memphis cash prices is seen from the error decompositions, table 2. Note that for 1985, the Memphis price was influenced by shocks in the futures price series only at very short horizons and that the futures price influence decayed to near zero within two weeks. The isolation of the Memphis price from the futures market is quite noticeable in the pre-August 1986 decompositions. Here virtually more of its error uncertainty is attributable to shocks in the futures market. Contrast this with the post-August 1 decompositions where up to 30% of the uncertainty in Memphis price is attributable to shocks in the futures price series.

Table 3 Decomposition of Within-Sample Innovation Variance on Memphis Cash Prices by Series and Horizon

	<u>World price</u>	<u>Futures price</u>	<u>Memphis</u>
Horizon	(1985)		
0	.00	.11	.89
1	.00	.05	.95
3	.00	.04	.96
10	.01	.03	.96
	(1986, prior to August 1)		
0	.00	.00	1.00
1	.00	.00	1.00
3	.00	.01	.01
10	.00	.01	.01
	(1986, after August 1)		
0	.01	.01	.98
1	.04	.05	.91
3	.07	.12	.81
10	.13	.31	.56

V. CONCLUDING REMARKS

This paper has explored various specification issues involved in the construction of a structural econometric model for futures market studies. We have argued that previous modeling efforts have not considered fully the stochastic, dynamic, simultaneous and general equilibrium properties. Such specifications can cause severe restrictions on modeling intertemporal price relationships in spot and futures markets. When spot and futures prices are viewed within a simple framework of conditional expectations, taking into accounts the stochastic interactions of information shocks in each markets, the model becomes particularly useful for analysis of policy shocks and exogenous disturbances.

In this study we demonstrate the utility of a two equation system for a simultaneous determination of spot and futures price in response to changes in market expectations. This conditional expectation formulation provides useful insights into the development of a simultaneous equations structural model for intertemporal pricing dynamics. Based upon this simple specification, structural model information can also be utilized in developing reduced form equations and for testing impulse response hypotheses in a vector autoregressive framework.

In a recent study, we attempted to combine a structural model with a vector autoregression to enhance accuracy of commodity price forecasts. Empirical test from this composite approach have not yielded the expected improvement for the various forecasting situation (Chen and Bessler). However, the incorporation of the structural model information into vector autoregression analysis seems to be particularly useful in suggesting hypotheses for policy impact analysis. The very simple structural model developed in this paper demonstrates the important role of market expectations in spot

and futures price determination. This formulation may also be useful for further econometric model development which emphasize the stochastic, dynamic, simultaneous and general equilibrium properties of the structural model specification.

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