Cotton Price Model

Theoretical Model

The general framework for the cotton price model is based on the theory of competitive markets, in which the market price results from allocating available supplies to alternative product uses (e.g., Tomek and Robinson, 2003, p. 406). For the U.S. cotton market, the identity between supply and demand can be written as:

$$I_t + Q_t + X_t = I_{t-1} + A_t + M_t \qquad (1)$$

where I_t = ending inventory,

I_{t-1} = beginning inventory,

Q_t = domestic consumption,

X_t = exports,

A_t = domestic production, and

M_t = imports.

At the beginning of the marketing year denoted by t, the variables on the right-hand side can be treated as predetermined.[3] Therefore, the above identity results in the demand for domestic uses, the demand for exports, and the demand for inventories at a given level of supply. To simplify, the demand for domestic uses and the demand for exports may be summed to represent current demand (D_t). Similarly, the sum of beginning inventory, domestic production, and imports reflects current supply (S_t). This allows the identity to be expressed as:

[3]Imports are not predetermined, but are trivially small compared with domestic production.

$$S_t - D_t - I_t = 0 \qquad (2)$$

Each variable in the identity is a function of a set of explanatory variables:

$$S_t = b(E_{t-1}(p_t), z_t)$$

$$D_t = g(p_t, y_t)$$

$$I_t = h(p_t, w_t)$$

where p_t is the inflation-adjusted price, $E_{t-1}(p_t)$ is the period t-1 expectation of p_t, and z_t, y_t, and w_t are exogenous variables affecting supply, demand, and stocks, respectively. All other variables are as defined previously. Supply is positively related to expected price while demand and stocks are negatively related to price. Assuming that supply is predetermined at the beginning of the marketing year, equation 2 can be expressed as:

$$S_t - g(p_t, y_t) - h(p_t, w_t) = 0. \qquad (3)$$

Traditionally, in forecasting models price is specified as a function of the stocks-to-use ratio (e.g., Westcott and Hoffman, 1999). Stocks-to-use ratio can be introduced in equation 3 by dividing through by $g(p_t, y_t)$:

$$\frac{S_t}{g(p_t, y_t)} - 1 = \frac{h(p_t, w_t)}{g(p_t, y_t)} = r(p_t, w_t, y_t), \tag{4}$$

where r denotes the ratio of stocks to use. Equation 4 is the implicit price equation. To find an explicit equation for price, we differentiate equation 4:[4]

[4]Since the time (t) indicator is identical for all variables, it is omitted from the following mathematical derivations.

$$dS = dr(g) + \frac{\partial g}{\partial p}dp + \frac{\partial g}{\partial y}dy + \left(\frac{\partial g}{\partial p}dp + \frac{\partial g}{\partial y}dy\right)r. \tag{5}$$

Solving dS for dp, we obtain the following equation for a change in price:

$$dp = \left((r+1)\frac{\partial g}{\partial p}\bigg|_y\right)^{-1} dS - g\left((r+1)\frac{\partial g}{\partial p}\bigg|_y\right)^{-1} dr - \left(\frac{\partial g}{\partial p}\right)^{-1}\frac{\partial g}{\partial y}dy \tag{6}$$

Equation 6 shows that change in price can be accurately approximated as a function of stocks-to-use ratio and demand shifters only when change in supply (dS) is very small or when change in stocks-to-use is much greater than change in supply ($dr >> dS$). Thus, equation 6 provides a more complete model of price changes when neither of these two conditions is satisfied. The result is a model that differs from the traditionally specified models (e.g., Meyer, 1998) since supply is now recognized as a variable distinct from stocks. Given the problems with forecasting cotton prices in recent years, pursuing alternatives to the traditional specification seems appropriate.

This specification models cotton price in first-difference terms, which has implications with respect to its time-series properties. For price levels, the hypothesis of a unit root cannot be rejected (with an Augmented Dickey-Fuller test statistic of -1.5). However, for the price series in percentage change form, the hypothesis that a unit root is present can be rejected at the 1-percent significance level (ADF = -8.4), and ordinary least squares estimation of the model will be efficient and unbiased.

Price enters this model in real rather than nominal terms. This bears discussion since commodity price forecasting models commonly omit any discussion of inflation, and specify their models in nominal terms. Van Meir (1983) specifies his model in real terms (deflating with U.S. the gross national product implicit deflator), but does not discuss the model's derivation. Goodwin et al. (2005) consider the role of inflation, and test specifications with inflation as an independent variable in their model, which forecasts nominal prices. Both including inflation as a variable and forecasting a deflated price when the ultimate goal is a nominal price forecast put the forecaster's results at the mercy of the available forecasts of inflation. However, if inflation should be accounted for, a model that completely omits it will see its usefulness diminished in other ways.

Given that this model's reduced form is based on a theoretical model with predetermined supply but demand as a function of price, real rather than nominal price is the appropriate dependent variable. Demand is almost invariably modeled as a function of real rather than nominal prices (Ferris, 2005), and a broad measure of inflation was chosen since cotton products will be competing with a broad range of products for consumer demand. Furthermore, given that the nominal loan rate is not an independent variable in this model, the use of real prices does not adversely affect the role of the independent variables as it would for some of the earlier models.

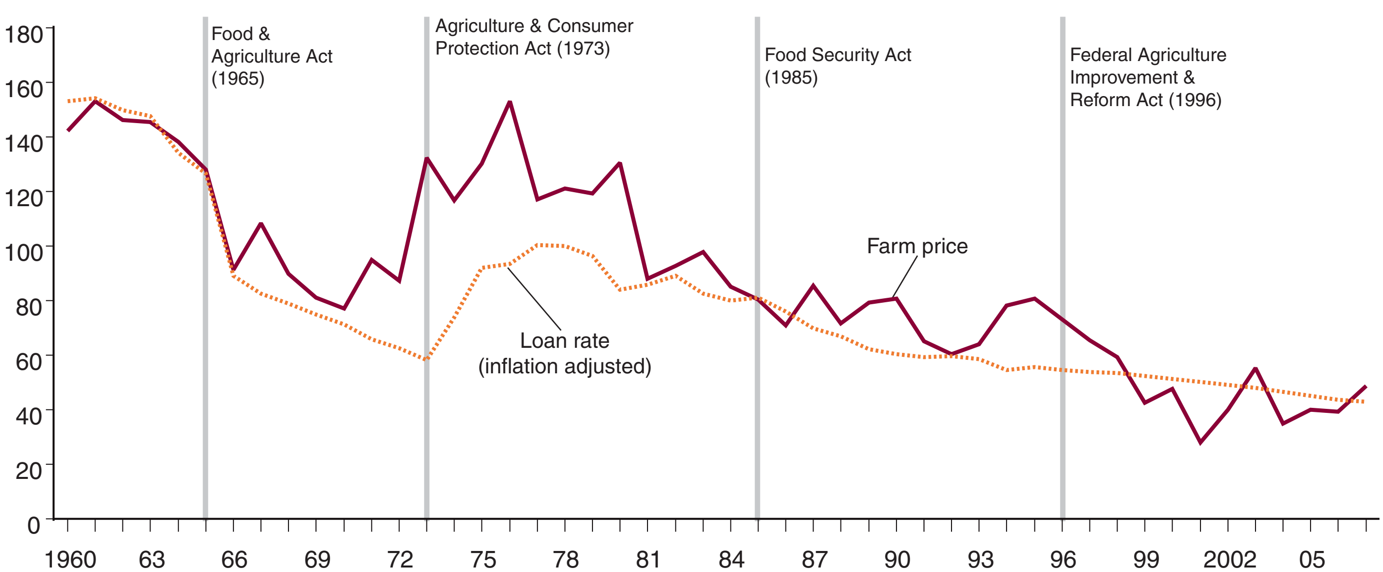
Empirical Analysis

The U.S. cotton price has been highly variable over time under the pressure of various economic and political factors (fig. 1). Equation 6 provides a reduced-form model for evaluating percent changes in U.S. average farm price (*dp*) based on changes in U.S. supply (*dS*), U.S. stocks-to-use ratio (*dr*), and a set of demand shifters. A significant demand shifter in U.S. and world cotton markets is export demand changes associated with China's trade policy. The strong correlation between world cotton prices and China's net trade was noted as early as 1988 by the ICAC, and the level of China's net trade was included in the International Cotton Advisory Committee's world price forecasting model for the 1974/75-1986/87 period (ICAC, 1988). Similarly, MacDonald (1997) adjusted the world (minus China) stocks-to-use variable by the amount of China's net trade in another world price model, estimated using 1971/72–1995/96 data. In 2001, researchers at USDA's Economic Research Service highlighted how China's domestic cotton policy drove its cotton trade, with significant impacts on world markets:

Figure 1

U.S. season-average farm price for upland cotton, 1960-2007

Cents/pound (adjusted to 2000 dollars)



Source: ERS calcuations based on data from NASS and the U.S. Department of Commerce.

> "Stocks rose after 1994/95 as China raised its farm prices while maintaining an open trade regime. China's government-mandated farm prices proved difficult to reduce as world prices fell, and restricting imports seemed inconsistent with ensuring the profitability of its huge textile industry. Also, government policy locked older cotton in stocks in order to prevent bookkeeping losses as the market value of procured cotton tumbled below the cost of purchasing, processing, and storage. Stocks reached a staggering 106 percent of use in 1998/99, and China accounted for 47 percent of the entire world's cotton ending stocks. Then, starting in 1998/99, the government began applying quantitative restrictions to cotton imports and subsidizing exports. In 1999/2000 the government effectively cut farm prices by refusing to guarantee procurement, and in 2000/01 a program to allow the central government to absorb the cost of marketing losses for stockpiled cotton went into high gear, opening the floodgates for enormous government stocks to flow into the market. By 2000/01, China had cut its ending stocks by nearly 10 million bales, mostly from government stocks (USDA/ERS, 2001)."

This demand shifter is measured in this report as an absolute change[5] from the previous 2-year average of China's net imports as a share of world consumption:

$$CN_t = \frac{M_t^{China} - X_t^{China}}{Q_t^{World}}. \quad (7)$$

Thus, the empirical price model is specified as:

$$\frac{(p_t - p_{t-1})}{p_{t-1}} = \alpha_0 + \alpha_1 \frac{(S_t - S_{t-1})}{S_{t-1}} + \alpha_2 \frac{(r_t - r_{t-1})}{r_{t-1}} + \alpha_3 \left(CN_t - average(CN_{t-1}, CN_{t-2})\right), \quad (8)$$

where all variables refer to U.S. values unless otherwise stated.[6] Since supply is predetermined, changes in supply have an inverse effect on price. Changes in stocks-to-use ratio are also negatively related to price. Increases in China's net cotton imports represent a greater export demand for U.S. cotton and thus have a positive relationship with price changes.

Another factor affecting the relationship between U.S. ending stocks and prices is government policy. The two most relevant policies to cotton prices are the loan program and the User Marketing Certificate Program (generally referred to as "Step 2" of the marketing loan program) (see Meyer et al., 2007, for a summary of U.S. farm programs affecting cotton). Since the relationship between how the loan program affects prices and how stocks affect prices in this model is relatively straightforward, a simple demand shifter can be created to account for the loan program. Step 2's effects were accounted for by adjusting the dependent variable for its impacts.

Before 1986, U.S. commodity programs sometimes served to establish a price floor for U.S. crops. USDA's Commodity Credit Corporation (CCC) acquired large stocks of cotton (and other commodities) during the early 1980s as market prices in the United States fell toward U.S. loan rates (table 1). Stocks owned by CCC were not available to the market, and prices were higher than if the stocks

[5]Absolute changes from the previous 2-year average are used instead of percent change relative to the previous year because of the sporadic changes in this variable, which cause small absolute changes to appear very large in percentage form.

[6]The choice of percentage change as the functional form followed from the theoretical model's derivation in differences. Alternatives—such as using the variables in levels or logs—also resulted in less accurate out-of-sample forecasts.

could have been drawn upon to satisfy demand. Furthermore, even cotton that had not yet been acquired by CCC, but was still being used as collateral in the loan program, was also not freely available for spinning, export, or private stockholding. The shift of U.S. cotton policy to a marketing loan program meant that CCC acquisition of cotton was significantly reduced, and in 2006 CCC instituted a policy of immediately selling any forfeited cotton, ensuring negligible CCC stocks at the end of the marketing year. However, the ability of producers to place their cotton in the loan program affected prices after 1986, and the volume of cotton remaining as collateral in the loan program at the end of the marketing year was often significant, even in recent years. While current legislation dictates that the maximum duration of a loan is 9 months, before 1996 cotton was permitted to remain under loan as long as 18 months. Given that cotton continues to enter the loan in the beginning months of each calendar year, cotton can remain under loan for several months after the end of the marketing year (July 31), even under current rules. Storage costs are, unlike with grains, covered by the CCC when the redemption price applicable to the loan is below the loan rate. This further encourages producers to delay marketing their cotton when the loan program is a sound alternative.

Table 1

Season-ending U.S. commodity program cotton stocks, 1974/75-2007/08

Marketing year	CCC inventory	Collateral on outstanding loans	Inventory as share of use
	1,000 bales	*1,000 bales*	*Percent*
1974/75	0	901	9
1975/76	0	110	1
1976/77	0	309	3
1977/78	0	1,209	10
1978/79	1	614	5
1979/80	0	501	3
1980/81	0	626	5
1981/82	1	3,643	31
1982/83	396	4,267	43
1983/84	158	444	5
1984/85	124	1,597	15
1985/86	775	5,965	80
1986/87	69	2,914	21
1987/88	5	3,164	22
1988/89	92	4,119	30
1989/90	27	430	3
1990/91	1	215	1
1991/92	3	297	2
1992/93	13	558	4
1993/94	13	179	1
1994/95	0	165	1
1995/96	0	312	2
1996/97	0	311	2
1997/98	0	61	0
1998/99	6	326	2
1999/2000	2	68	0
2000/01	5	1,460	9
2001/02	108	665	4
2002/03	97	668	4
2003/04	0	1,371	7
2004/05	2	301	1
2005/06	5	1,185	5
2006/07	51	857	5
2007/08	0	3,819	21

Sources: Stultz et al., Farm Service Agency (FSA), and ERS calcuations based on data from FSA and World Agricultural Supply and Demand Estimates..

Therefore, a variable was created representing the sum of both cotton owned by CCC and of cotton with CCC loans still outstanding at the end of the marketing year. This was divided by cotton use for that year to create an additional demand shifter:

$$CCC_t = \frac{h_t^{CCC} + h_t^{loan}}{Q_t + X_t} \quad (9)$$

where h_t^{CCC} is the cotton owned by CCC at the end of the marketing year and h_t^{loan} is the volume of cotton remaining as collateral in the loan program at that time. By capturing all of the cotton involved in the loan program instead of just the cotton owned by CCC, the variable more accurately captures how the loan program supports prices. The loan rate appears to have functioned as a price floor in 1981, 1982, and 1984, but stocks from cotton produced in those marketing years were not acquired by CCC until the next marketing year. To correctly attribute the impact of the loan program to those years rather than to the subsequent years, the actual loan rate or another variable would have to be added (as in Westcott and Hoffman, 1999). Equation 9 allows the impact of the loan program to be accounted for with one variable.

Another government policy that affected cotton markets is the U.S. Step 2 program, which was introduced in 1990 and continued until 2006. The Step 2 program offered payments to U.S. textile mills and U.S. exporters when the price of U.S. cotton in Northern Europe exceeded the world price of cotton, as measured in Northern Europe. A World Trade Organization (WTO) panel in 2005 found the program in violation of the General Agreement on Tariffs and Trade (GATT), in large part because the payments to U.S. mills were exclusively for the consumption of U.S. cotton rather than either U.S. or imported cotton (see Schnepf, 2007, for a summary of the dispute). In the program's early years, the seasonality of the price spread that determined Step 2 payments and the seasonality of U.S. export sales coincided. Therefore, exports accounted for a disproportionate share of the payments in those years. The ability of exporters to lock in payments for much of the year's exports within a relatively small window of time was also a factor. As a result, Step 2 was often perceived to be primarily an export subsidy. However, regulatory changes in the program were frequent, and domestic U.S. payments exceeded payments to exporters in later years.

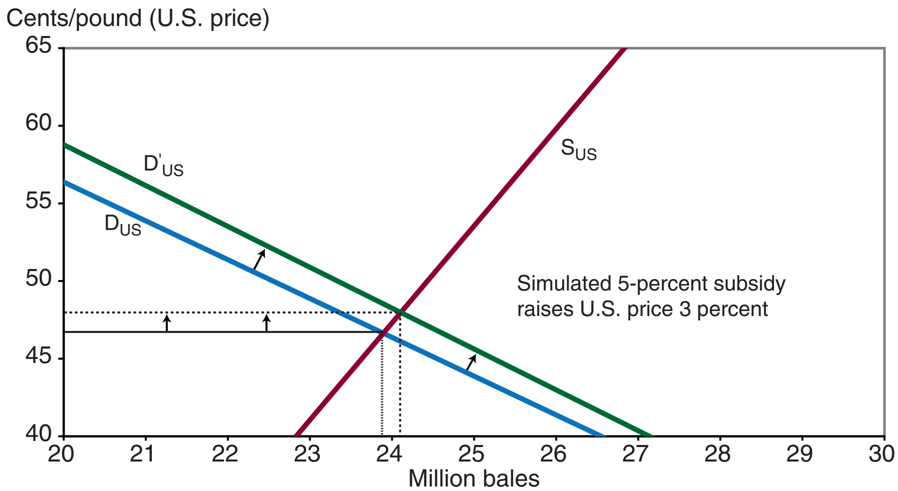
During much of the program's tenure, payments to exporters were made at the time of shipment rather than sale. Sales for exports typically occur 9-10 weeks before shipment, and sometimes much further in advance. Since the magnitude of Step 2 payments fluctuated weekly, this added uncertainty to the relationship between the price of export sales and the subsidy associated with the shipment. This, and the fact that payments were made to the firms exporting the cotton rather than those actually purchasing it, made the link between Step 2 payment and subsidization of export demand indirect. However, the subsidies averaged 5 percent of the value of U.S. cotton use during 1991-2006. Since U.S. cotton accounted for about 20 percent of global cotton use during this time, the program likely had an impact on the world price as well as the U.S. price. The Step 2 program was terminated in August 2006 as part of the United States' efforts to comply with the WTO panel's findings. Step 2 therefore is no longer a factor in the determination of prices, but must be accounted for when analyzing historical price data.

The simplest way to understand the impact of the Step 2 program is to abstract from the differing effects on U.S. export and domestic demand and simply consider it as a subsidy for consumption of U.S. cotton anywhere in the world (figures 2 and 3).[7] The introduction of the subsidy would shift the demand for U.S. cotton upward from D_{US} to D'_{US} (fig. 2), and the demand for the rest of the world's (ROW) cotton downward from D_{ROW} to D'_{ROW} (fig. 3). The new equilibrium would have production and consumption of U.S. cotton slightly higher than in the absence of a subsidy, and slightly lower for ROW. Similarly, the price of cotton in the United States would be higher, and would rise to a greater degree than the decline in the ROW's price. Simulations by FAPRI (2005) and Mohanty et al. (2005) found similar impacts, with the removal of Step 2 leading to a U.S. price that was 2.9 percent lower, on average, and a world price that was slightly higher (less than 1 percent).

[7]While the core of Step 2 was to convey payments to consumers of U.S. cotton either directly or indirectly, the details and history of the program are complex (Meyer and MacDonald, 2001).

Figure 2

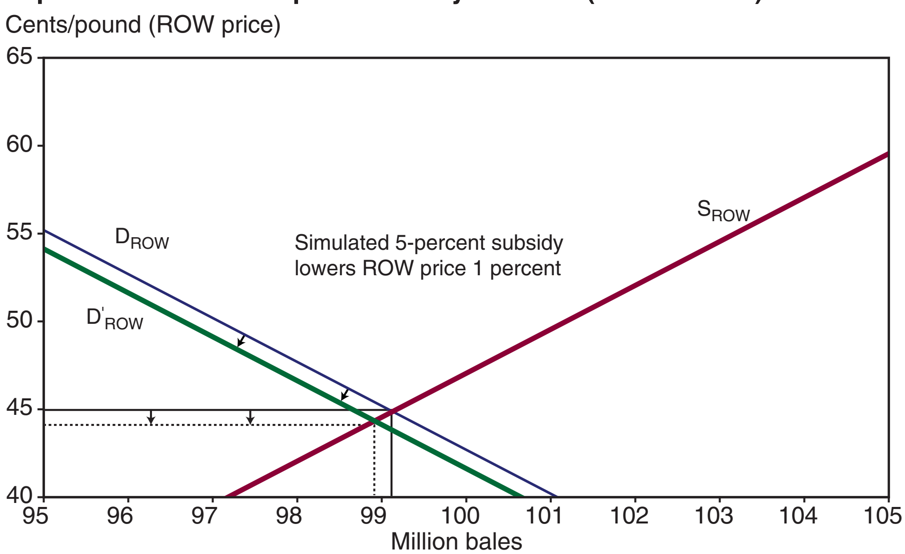
Impact of U.S. consumption subsidy on U.S. cotton



Source: Simulation of model with linear supply and demand for U.S. and rest of world, substitution between U.S. and ROW cotton, and calibrated to approximate recent realizations of the variables.

Figure 3

Impact of U.S. consumption subsidy on ROW (rest of world) cotton



Source: Simulation of model with linear supply and demand for U.S. and rest of world, substitution between U.S. and ROW cotton, and calibrated to approximate recent realizations of the variables.

Since Step 2 will no longer be a factor in U.S. prices, and since it influenced past prices, the forecasting model was estimated with data for the dependent variable adjusted to remove the past impact of Step 2. Data on spending for Step 2 payments in each year were divided by the value of U.S. cotton use to determine the relative subsidy provided each year (table 2). An adjustment variable (λ_t) was constructed so that each year's price adjustment was proportional to that year's subsidy; the average for the adjustment variable over 1991-2006 is 2.9 percent. Thus, if S_t equals a given year's subsidy, then $\lambda_t = 0.029 * S_t / (\Sigma S_t / T)$, where T = number of years between 1991 and 2006. This variable was used to adjust the U.S. season-average upland farm price to remove the impact of Step 2:

$$p_t = \frac{p_t^{NASS}}{GDPDEF_t} \text{ and } p_t^* = \frac{(1-\lambda_t)p_t^{NASS}}{GDPDEF_t}. \quad (10)$$

Here we define p_t more explicitly as the season-average price reported by USDA's National Agricultural Statistics Service (p_t^{NASS}), deflated by the U.S. Department of Commerce's gross domestic product price index ($GDPDEF_t$).[8]

Thus, the cotton price model adjusted for the impact of the government programs is:

$$\frac{(p_t^* - p_{t-1}^*)}{p_{t-1}^*} = \alpha_0 + \alpha_1 \frac{(S_t - S_{t-1})}{S_{t-1}} + \alpha_2 \frac{(r_t - r_{t-1})}{r_{t-1}} + \alpha_3 \left(CN_t - average\ (CN_{t-1},\ CN_{t-2})\right) + \alpha_4 CCC_t. \quad (11)$$

[8]An alternative to this procedure would be to continue to define price as p_t rather than p_t^*, and instead include Step 2 payments or subsidy levels as an independent variable. We chose to adjust the dependent variable, as described, due to higher out-of-sample forecasting accuracy of the model using this approach.

Table 2
Step 2 expenditures and price adjustment variable

Marketing year	Payments[1]	Payments/cotton use	Subsidy (S_t)	Adjustment (λ_t)[2]
	$ Million	*$/pound*	*Percent*	*Percent*
1991/92	140	0.02	2.9	1.6
1992/93	114	0.02	2.7	1.5
1993/94	149	0.02	2.5	1.5
1994/95	88	0.01	1.0	0.6
1995/96	34	0.00	0.5	0.3
1996/97	6	0.00	0.1	0.1
1997/98	416	0.05	6.4	3.7
1998/99	280	0.04	6.7	3.9
1999/2000	445	0.05	10.4	6.0
2000/01	236	0.03	5.5	3.2
2001/02	182	0.02	4.9	2.8
2002/03	455	0.05	8.9	5.1
2003/04	363	0.04	5.5	3.1
2004/05	582	0.06	10.7	6.2
2005/06	397	0.04	6.2	3.6
Average	259	0.03	5.0	2.9

[1]Fiscal year.
[2]Derived from annual subsidy so that the 1991-2005 average adjustment is 2.9 percent, and each year is proportional to that year's subsidy: $\lambda_t = 0.029 * S_t / (\Sigma S_t / T)$.
Sources: USDA's Farm Service Agency (FSA), and ERS calculations based on data from the FSA, *World Agricultural Supply and Demand Estimates,* and *Cotlook*.

Another factor that may have an important effect on cotton prices is energy prices. Previous work (e.g., Barsky and Kilian, 2002) has indicated how oil price shocks can affect prices in general. More recently, policy changes—like those regarding ethanol—have linked energy and grain prices (Westcott, 2007). Energy market shocks occurred in the 1970s and again after 2004. In an effort to develop a model that is robust to both high and low energy prices, and to a variety of policy environments, this study concentrates on cotton price movements starting from the 1974/75 marketing year and extending to 2007/08. Since the proposed model is estimated in reduced form, the impact of energy prices is included implicitly through the supply variable. A similar argument can be made about other supply-inducing variables, such as the price of cotton seed.