U.S. Cotton Prices and the World Cotton Market: Forecasting and Structural Change

Olga Isengildina-Massa and Stephen MacDonald[1]

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*Assistant Professor in the Department of Applied Economics and Statistics at Clemson University and Senior Economist Economic Research Service, respectively. The authors appreciate the research assistance of Michael D. Scott, the Graduate Student at Clemson University. The funding support of the U.S. Department of Agriculture under Cooperative Agreement 58-3000-7-0063 is gratefully acknowledged. Any opinions, findings, conclusions, or recommendations expressed in this document are those of the authors and do not necessarily reflect the view of the U.S. Department of Agriculture.

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Introduction

Agricultural prices are notoriously difficult to forecast due to shocks from weather events around the world, the important role of government policy in the marketplace, and changing tastes and technology. In addition, agricultural prices are affected by the shocks affecting the rest of the economy, including macroeconomic policy and shifts in energy markets. Forecasts of agricultural prices are important to both private and public policy-makers, as well producers and consumers of agricultural products. Therefore, agricultural price forecasting is a widespread activity. USDA alone publishes updates of price forecasts for 24 commodities every month in its *World Agricultural Supply and Demand Estimates*. However, until recently USDA was legally prohibited from forecasting cotton prices.[2] Cotton price forecasts were available each month from the International Cotton Advisory Committee (ICAC) and—with less frequent updates—from the Food and Agricultural Policy Research Institute (FAPRI), the Australian Bureau of Agricultural and Resource Economics (ABARE), and the World Bank. In addition, although USDA did not publish cotton price forecasts, the USDA's Interagency Commodity Estimates Committee (ICEC) for cotton calculated unpublished estimates of world and domestic cotton prices each month. In recent years, USDA and other agencies have observed systematic errors in their cotton price forecasting models, highlighting the need for a thorough review of price relationships. The removal of the ban on cotton price forecasting by USDA in the 2008 Farm Bill has made the need to review existing cotton price forecasting procedures and develop of a new forecasting model an urgent one.

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[2] In 1929, Congress passed legislation forbidding USDA from publishing cotton price forecasts (see Townsend (1989) for a discussion of the circumstances surrounding this legislation).

This paper develops a theoretically-based reduced-form specification for a cotton price forecasting model. Like earlier models for cotton (Meyer, 1998; Valderrama, 1993; Goreux, et al., 2007)), wheat (Westcott and Hoffman, 1999), corn (Van Meir, 1983; Westcott and Hoffman, 1999), and soybeans (Plato and Chambers, 2004; Goodwin, Schnepf, and Dohlman, 2005), the U.S. season-average farm price is a function of U.S. stocks/use. Other variables include U.S. and world cotton supply and a set of shift variables accommodating circumstances particular to cotton markets. The empirical version of the model includes a demand shifter for China's trade and another shifter for the impact of U.S. commodity policy. Testing indicates evidence of structural change, which is likely the result of the U.S. shift from domestic cotton consumption to exporting, and the model is adjusted to include impacts of foreign supply.[3]

Data

This study concentrates on the marketing year average U.S. farm price of upland cotton, with the historical data over 1973 through 2007 collected from the USDA's National Agricultural Statistics Service (NASS) database and publications (USDA-NASS, 2008). One-year-ahead forecasts for U.S., world, and China supply and use categories are published in monthly USDA *World Agricultural Supply and Demand Estimates* (WASDE) reports from the USDA's World Agricultural Outlook Board (USDA-WAOB, 2008). These forecasts will provide the out-of-sample values for the independent variables in future years. The data for the past realizations of cotton supply and demand were drawn from the "Production, Supply and Distribution Online" database maintained by USDA's Foreign Agricultural Service (USDA-FAS, 2008). Unlike wheat and feed grains, USDA does not publish forecasts and historical estimates of Commodity

[3] Foreign supply is an important factor for U.S. cotton prices because the United States is one of the largest producers and exporters of cotton in the world market and as such directly competes with cotton coming from other countries.

Credit Corporation (CCC) end of year stocks in the monthly WASDE. CCC cotton stocks are forecast twice a year in order to project budgetary outlays, and historical data for CCC cotton stocks were provided by USDA's Farm Service Agency (FSA). Data on expenditures for the U.S. User Market Certificate Program ("Step 2") were also provided by FSA. Since the "Step 2" program ended in August 2006, forecasts will not be necessary for future years.

Cotton Price Model

Theoretical Model

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

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

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[4]. 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,

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

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:

(2) $$S_t - D_t - I_t = 0 .$$

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

$$S_t = b(E(p_t), z_t)$$

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

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

where p_t is the inflation-adjusted price, $E(p_t)$ is expected price, z_t, y_t, and w_t are exogenous variables affecting supply, demand, and stocks, respectively and 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:

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

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

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

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[5]:

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

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

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

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

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 none of these two conditions are satisfied. The result is a model that differs from the traditionally specified models (e.g. Meyer, 1998 and others mentioned in introduction) since supply is now recognized as variable distinct from stocks. Given the problems with forecasting cotton prices in recent years, pursuing alternatives to the traditional specification seems very 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 a number of previous commodity price forecasting models were specified in nominal terms. Most of the studies reviewed omit any discussion of inflation, and specify their models in nominal terms. Van Meir (1983) specifies his model in real terms (deflating with the gross national product implicit deflator), but does not discuss the model’s derivation. Goodwin, Schnepf and

Dohlman 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 prices are the appropriate dependent variable. Demand is almost invariably modeled as a function of real rather than nominal prices (see Ferris, 1998), 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

Figure 1 shows changes in the U.S. marketing year average farm price of upland cotton over 1960/61 though 2006/07. This figure shows that U.S. cotton price has been highly variable over time under the pressure of various economic and political factors. Equation 7 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 demand shifter that appears perhaps most relevant during the period of study is export demand 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 ICAC's world price forecasting model for the 1974/75 through 1986/87 period (ICAC, 1988). Similarly, MacDonald (1998) 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 through 1995/96 data. In 2001, USDA highlighted how China's domestic cotton policy drove its cotton trade, with significant impacts on world markets:

> "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 (Market and Trade Economics Division, 2001)."

This demand shifter is measured in this study as an absolute change[6] from the previous two-year average of China's net imports as a share of world consumption:

(8)
$$CN_t = \frac{M_t^{China} - X_t^{China}}{D_t^{World}}$$

Thus, the empirical price model is specified as:

(9)
$$\frac{(p_t - p_{t-1})}{p_{t-1}} = \alpha_0 + \alpha_1 \frac{(S_t - S_{t-1})}{S_{t-1}} + \alpha_2 \frac{(r_t - r_{t-1})}{r_{t-1}} + \alpha_3 \left(CN_t - average\,(CN_{t-1}, CN_{t-2}) \right)$$

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

where all variables refer to U.S. values unless stated otherwise. 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. Greater China net 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, MacDonald, and Foreman, 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 1980's as market prices in the United States fell below U.S. loan rates (Table 1). Stocks owned by CCC were not available to the market, and prices were higher than if the stocks 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 adjustment of the U.S. cotton program to a marketing loan meant that CCC acquisition of cotton was significantly reduced, and in 2006 CCC instituted a policy of immediately selling any forfeited cotton, ensuring CCC stocks remain essentially at zero at the end of the marketing year. However, the ability of producers to place their cotton in the loan program still 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. If cotton under loan has not been acquired by CCC, then the maximum duration of its stay under loan is 9 months. Given that cotton continues to enter the loan in the months after January of each year, cotton can remain under loan for several months after the end of the marketing year. Note also that unlike with grains, storage costs are covered by the CCC when the redemption price applicable to the loan is below the loan rate. This further enhances the incentive of producers to delay marketing their cotton when the loan program is a sound alternative.

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

$$CCC_t = \frac{h_t^{CCC} + h_t^{loan}}{D_t} \tag{10}$$

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 the 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 price floor in 1981, 1982, and 1984, but stocks from cotton produced in that marketing year were not acquired by CCC until the next marketing year. In order to capture the functioning of the loan program in those years, the actual loan rate or another variable would have to be added (as in Westcott and Hoffman, 1999). Equation 10 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 the 1990 U.S. farm legislation. 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, also measured in Northern Europe. A World Trade Organization (WTO) panel found the program in violation of the General Agreement on Trade and Tariffs (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 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 effected at the time of shipment rather than sale. Sales for exports typically occur 9-10 weeks before shipment, and occasionally substantially 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. When this is taken into account along with the fact that payments were made to the firms exporting the cotton rather than purchasing it, the link between Step 2 payment and subsidization of export demand is not as direct as it could be. However, the subsidies were non-trivial, equaling 5 percent of the value of U.S. cotton use on average during 1991-2006. Given that U.S. cotton accounted for about 20 percent of global cotton use during this time, it is reasonable to expect that the program had an impact on world price as well as 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 is nonetheless a factor to be accounted for in any analysis relying on historical 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 (Figures 2 and 3). The introduction of the subsidy would shift the demand for U.S. cotton upward from D_{US} to $D`_{US}$, and the demand for the rest of the world's (ROW) cotton downward from $D_{ROW}$ to $D`_{ROW}$. 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 U.S. price of cotton 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 such an impact, with the two studies predicting on average that removing Step 2 would mean a 2.9 percent lower U.S. price and a less than 1 percent higher world price. 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 was divided by the level 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 adjustment was proportional to that year's subsidy, and the average value of the adjustments over 1991-2005 was -2.9 percent. This variable was used to adjust the U.S. season-average upland farm price to remove the impact of Step 2.

$$(11) \qquad p_t = \frac{p_t^{NASS}}{GDPDEF_t} \quad and \quad p_t^* = \frac{(1-\lambda_t)\, p_t^{NASS}}{GDPDEF_t}$$

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

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

$$(12) \frac{(p_t^* - p_{t-1}^*)}{p_{t-1}^*} = \alpha_0 + \alpha_1 \frac{(S_t - S_{t-1})}{S_{t-1}} + \alpha_2 \frac{(r_t - r_{t-1})}{r_{t-1}} + \alpha_3 \left(CN_t - average\,(CN_{t-1}, CN_{t-2})\right) + \alpha_4 CCC_t$$

Other factors that may have an important effect on cotton prices include 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 have linked energy and grain prices (Westcott, 2007). Energy market shocks occurred in the 1970's 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.

Structural Change Test

Following Wang and Tomek (2007) it is important to insure that a correctly specified model is used to test for structural change. Therefore, equation 12 is used to test for structural change. A traditional approach would be to pick an arbitrary sample breakpoint, often the midpoint of the sample, and use a Chow test for structural change. This could be further refined by associating breakpoints with major events relevant to the data series. Either of these approaches suffers from the arbitrary nature of the selected breakpoints. Recent literature suggests the Quandt-Likelihood Ratio (QLR) test is superior test for detecting structural change of unknown timing (e.g., Hansen, 2001). The QLR test consists of calculating Chow breakpoint test at every observation, while making sure that subsample points are not too close to the end points of the sample. The QLR test was applied to the pooled data in this study with 20% trimming. The highest value of the QLR statistic was 5.0 (figure 4). The probabilities for these statistics were calculated using Hansen's (1997) method. The critical values of the QLR statistic at the 99% significance level with five restrictions is 4.53 (Stock and Watson, p. 471), which indicates that the null hypothesis of no structural change is rejected. The maximum statistic of 5.0 was observed in 1999/00, which indicates the breakpoint location.

This structural break was likely caused by a combination of factors. Besides significant changes in international trade discussed earlier, which have been transitory in nature, this period coincided with some permanent fundamental regime changes in China's supply due to the end of guaranteed procurement prices. Some permanent changes also took place in China's consumption sector due to its growing textile industry. These regime changes in China's cotton sector are likely associated with China's accession to the WTO at the end of 2001. China joined the WTO just as the textile trade liberalization provisions of the Uruguay Round Agreement were having an impact. The phasing-out of developed country textile trade protection (commonly referred to as Multifiber Arrangement, or MFA) was an important factor behind the rapid increased export orientation of the US cotton industry. Figure 5 shows that in the early 2000s export demand surpassed domestic use of the U.S. upland cotton. As the export share of U.S. cotton use rose to levels not seen since the 19th century, the importance of world supply and demand to U.S. cotton prices increased.

In order to correct for the structural change detected in the estimated model (equation 12) an additional shift variable was included in the model to reflect an increased export orientation of the US cotton industry. The world market signals are assumed to be transmitted to the US market through the foreign supply, which was constructed excluding China's supply, but including China's net contribution to the global availability of cotton (net exports)[7]:

(13) $$S_t^{Foreign} = S_t^{Foreign} - S_t^{China} + X_t^{China} - M_t^{China}$$

Foreign supply is an important factor for U.S. cotton prices because the United States is one of the largest producers and exporters of cotton and as such directly competes with cotton coming from other countries. With this variable included, no structural break was detected and the specification of the model was complete. Thus, the final model specification is:

(14) $$\frac{(p_t^* - p_{t-1}^*)}{p_{t-1}^*} = \alpha_0 + \alpha_1 \frac{(S_t - S_{t-1})}{S_{t-1}} + \alpha_2 \frac{(r_t - r_{t-1})}{r_{t-1}} + \alpha_3 \left(CN_t - average\,(CN_{t-1}, CN_{t-2})\right) + \alpha_4 CCC_t + \alpha_5 \frac{\left(S_t^{Foreign} - S_{t-1}^{Foreign}\right)}{S_{t-1}^{Foreign}}$$

All data used for the empirical estimation of this equation are presented in Table 3. The model is estimated using the most recently available revisions of supply and demand categories.

Estimation Results

Table 4 presents the results of cotton price model estimation (equation 14) over the period from 1974/75 through 2006/07. The estimated model explains over 68 percent of the variation in US upland cotton price. All coefficients except that for the *Stocks/Use* variable are significant at the conventional levels and have the expected signs. Since most variables are

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[7] China's stocks and production were excluded from this shift variable since the stock data are particularly unreliable (MacDonald, 2007). Stocks were regarded as a state secret in China for many years, and although the degree of secrecy has diminished profoundly even current stock estimates for China are highly conjectural. Production data in China is also considered less reliable than elsewhere, so China's impact on world supply comes through its net trade position.

measured in percent changes, their coefficients are interpreted as elasticities. Thus, a one percent increase in U.S. *Supply* from the previous year will cause prices to drop by about 0.7 percent. The impact of the *Stocks/Use* variable is not statistically different from zero at the 10 percent level. A one million bale increase in *China NI* (net imports) from the average of the previous two years will cause the U.S. average farm price of upland cotton to increase by 3.1 percent relative to the previous year's level. An increase in *CCC* stocks equal to three percent of U.S. use would raise price by 0.4 percent. *Foreign Supply* changes have approximately a one-to-one inverse effect on price. According to Pearson correlation coefficients presented in table 5, significant correlation exists between the *Stocks/Use* variable and several other explanatory variables in the model. Multicollinearity caused by this variable may inflate standard errors and R-squared statistic of the model. This issue was investigated by dropping stocks-to-use variable which resulted in very minor changes (in the second decimal) in the standard errors and the R-squared and no changes in the signs of the coefficients. Thus it was concluded that multicollinearity did not cause significant problems in our model.

Note that the low significance of the *Stocks/Use* variable highlights some differences of this model from past models, and the changes in world cotton markets. Before adjusting for the structural change (i.e. estimating equation 12), the parameter for stocks/use is significant at the 12 percent level with the full sample, and if equation 12 is only estimated with data through 1999, the variable is significant at the three percent level. This is despite the presence of significant collinearity with the *CCC* variable in this subsample (65 percent correlation). In the full data set, the *Stocks/Use* variable is not statistically significant since the United States now accounts for its smallest share of world production since the early 1800's and prices are increasingly set by the supply and demand forces outside the United States.

The goodness of fit of the model in nominal prices is illustrated in figure 6. The nominal prices are calculated by removing inflation adjustment from the real prices predicted by the model and adjusting them for Step 2 payments. Converting real prices into nominal terms makes it easier to compare model predictions against the observed prices. Figure 6 demonstrates that the largest in-sample forecast error of 17.1 cents/lb occurred in 1988. The average forecast error for the entire sample is 0.2 cents/lb suggesting that the model is unbiased. However, the importance of these in-sample properties diminishes if the model does not forecast well.

Granger (2005) highlighted that the construction of a model's evaluation should be motivated by the model's purpose. While one purpose of this model is to discern the impact of supply and demand and policy variables on cotton prices to improve the understanding of these processes, the primary purpose of the model is to assist forecasting. Jumah and Kunst (2008) recently demonstrated with a set of grain price forecasting models that statistics assessing in-sample fit and those evaluating out-of-sample performances can give distinctly different rankings of model preference. For this exercise, a set of out-of-sample forecasts was calculated by reestimating the model with a truncated historical sample that ends in 2002/03 and using the parameters from this truncated sample to estimate subsequent out-of-sample forecasts. Four years of price forecasts (2003/04 to 2006/07) were calculated using data available in August 2008. Forecast performance was assessed relative to alternative forecasts.

The first alternative is the cotton forecasting model developed by Meyer in 1998. Meyer's specification is,

(15) $\ln(P) = f\,(\,\ln(S/U), CHFSTKS, Index, DUM_{SU}, \ln(LDP)^{*}\, DUM_{SU}, \ln(1{+}CCC/Use)),$

where: *CHFSTKS* = change in foreign (excluding China) stocks, *Index* = product of the September average of the price of the December futures contract and AMS's September estimate of the share of expected planted area already forward contracted, DUM_{SU} = dummy valued at 1 when *S/U* is less than or equal to 22.5 percent, *LDP* = the difference between the loan rate and effective loan repayment rate, and *CCC* = CCC inventory. Thus, the main difference between the proposed model and Meyer's model is that Meyer's model does not take into account changes in domestic and world supply (which was less relevant during the time that model was developed) but accounts for the impact of additional information through the index variable connected to futures prices.

The second alternative is the reduced form model developed by the WAOB in 2006 in an attempt to reflect the increased export orientation of the US cotton industry. This model's specification is,

(16) $P_t = f\,(WxC\ S/U_t,\ WxC\ S/U_{t-1},\ \text{China net exports}_t)$,

where: *WxC S/U* = world excluding China S/U.

The forecast from this model was used as one of the inputs in the USDA's cotton ICEC forecast. The biggest difference between the proposed model and the WAOB models is that WAOB models focuses on international forces, while the proposed model includes the combination of international and domestic components.

Alternative forecasts have been compared based on their individual mean error to test for bias, root mean squared error (RMSE) and mean absolute percent error to evaluate the size of the error, as well as Theil's U, with comparisons between forecasts based on the Morgan-Granger-Newbold (MGN) and Diebold-Mariano (DM) statistics (e.g. , Dirion, 2008).

Table 6 summarizes the proposed and alternative models' out-of-sample performance over 2003/04 through 2006/07. The first accuracy statistic presented for all forecasts is mean error, which is measuring the forecast bias. This statistic demonstrates the tendency of the WAOB model forecasts to overestimate cotton prices in the recent years, which was one of the motivations for the development of the new model. The mean error for the proposed model is one of the smallest suggesting that this model has been successful in reducing the bias in cotton price forecasts. The next two statistics, RMSE and MAPE evaluate the variance of the alternative forecasts. These statistics demonstrate that the proposed model compares favorably to the alternative model-based forecasts with the RMSE of 4.1 cents/lb and MAPE of 7 percent that are lower than those of alternative models. Theil's U statistics for all included models indicate that these forecasts are distinctly better than those of the naïve model, but the proposed model has the lowest (best) Theil's U of 0.31. Finally, alternative forecasts were compared to the benchmark of the proposed model using a Granger-Newbold-Mariano (GNM) test of the difference in accuracy of the proposed and the alternative model forecasts. The negative sign of the GNM statistic indicates lower accuracy relative to a benchmark. This test indicates that even with as little as four observations this model is significantly more accurate than the WAOB model (at the 10 percent significance level).[8]

Additional detail on out-of-sample performance of alternative forecasts is shown in figure 7. This figure plots specific errors of the alternative forecasts over 2003/04 through 2006/07. This figure shows that the proposed model had the smallest errors in 2003/04 and 2005/06, the largest error in 2006/07 and about average performance in 2004/05.

[8] Accuracy of this model deteriorates significantly if the dependent variable is switched from real to nominal prices. MAPE doubles in the out-of-sample test, while RMSE and bias also grows. Theil's U-statistic rises to above Meyer's and the GNM statistic falls so that this model is no longer more accurate than WAOB. Thus, adjusting for inflation helps improve the accuracy of the model.

Another important characteristic for a forecasting model is parameter stability. If estimated parameters change significantly as new observations are added, the out-of-sample forecasts may become highly volatile and less accurate, and the model may be misspecified. The parameter stability features of the proposed model are illustrated in table 7. This table shows that the parameter estimates are relatively unchanged when estimated using a 1974/75-2002/03 sample versus a 1974/75-2006/07 sample. Furthermore, the out-of-sample forecasts of the model estimated with the 1974/75-2002/03 sub-sample are only slightly less accurate than the in-sample estimated prices of the model using the full dataset. This stability bodes well for the model's usefulness in future forecasting.

Conclusions and Implications

This study sought to develop a statistical model that reflects current drivers of U.S. upland cotton prices in response to renewed authority for USDA to publish cotton prices and challenges with cotton price forecasting reported by various sources in the recent years. A review of the theoretical framework for commodity price forecasting suggested that changes in supply should be included in a cotton price model because of the rapid growth in supply due to the spread of genetically modified varieties and other technologies. Several demand shifters were also included in a model. China's net trade as a proportion of world consumption was included to account for changes in export demand associated with China's commodity and trade policies. The impacts of the U.S. farm policy were accounted for by including a variable representing the amount of cotton in the marketing loan program as a share of domestic consumption and by adjusting the dependent variable to reflect the impact of the User Marketing Certificate (Step 2) program.

The analysis of cotton price forecasting model identified a structural break that occurred in U.S. cotton industry in 1999. This structural break was likely caused by a combination of factors, one of which is an increased export orientation of the US cotton industry caused by the rapid contraction of the domestic textile industry following the phasing out of the Multifiber Arrangement (for more information on the end of the MFA, see MacDonald and Vollrath, 2005). Thus, the proposed model was modified to include the world supply of cotton to reflect the increased export orientation to correct for the observed structural change. The final model was subjected to extensive out-of-sample testing to ensure its appropriateness for forecasting.

The out of sample performance measures of the proposed cotton price model suggest that the model provides a considerable improvement over the naïve forecast. The parameter estimates and forecast errors do not change much between full sample, and reduced sample used for out-of-sample forecasting indicating the stability of the model. This stability suggests the model is an improvement over past forecasting models that have been challenged by the changing market conditions. Specifically, the out of sample forecasts from the proposed model are characterized by the lack of bias and relatively low variance. However, the in-sample root mean squared error of the nominal price predictions projected by this model is 6.0 cents, which is about 10 percent of the 1974/75-2006/07 average for U.S. upland cotton farm prices. These errors suggest that there may be some variables omitted from the model.

Omitted variables could include cotton quality characteristics, the role of polyester (cotton's primary substitute in textile spinning), the spread of technology like genetically-modified cotton, and lower transmission of grain price shocks to significant non-U.S. cotton producers. For example, Olmstead and Rhode (2003) demonstrate that the average staple length of U.S. cotton rose during the years comprising the historical sample used to estimate this model.

The U.S. season-average price is equivalent to the value of the crop of upland cotton divided by its volume, and staple length is one of the key determinants of the price of a particular bale, or lot, of cotton. Olmstead and Rhode's data started in 1957, when the U.S. upland crop averaged 32.75 sixteenths of an inch long. In 2006/07 and 2007/08 it averaged 35.3 sixteenths, an increase since 1957 that in 2007/08 would be worth about 2 cents per pound (Cotton Program, AMS). However, the impact of these qualitative characteristics on the price of cotton was not included in this study as it is very difficult to quantify.

Despite non-trivial errors, the proposed model provides useful information particularly in the environment of highly volatile commodity prices and the increased role of new players in futures markets. These developments and changing market institutions such as the rise of electronic trading have raised questions about the relationships among cash prices, futures prices, and supply and demand fundamentals. Specifically, there has been growing concern about changes in the relationship between futures prices and cash prices in the United States (Irwin, Garcia and Good, 2007). In March 2008, U.S. cotton futures demonstrated nearly unprecedented volatility. The basis between nearby futures and spot prices remained historically wide for several months afterward (Figure 6). Therefore, while it would be irrational to ignore the information provided by futures markets when forecasting the U.S. farm price of cotton, it is also important to have forecasts that are independent of that information.

The comparison of the out-of-sample performance of the proposed model to that of alternative models available from other sources revealed that the proposed model relatively superior to these alternative models. This comparison, however, does not include consensus-based forecasts that became publically available from the USDA WASDE reports since June 2008. The consensus forecasts were about as accurate as the proposed model, despite the handicap of preliminary supply and demand estimates. The advantage of the consensus forecasts is the ability to include additional information in the forecasting procedure that is hard to quantify within the framework of a statistical model. Among other things, this additional information would include the omitted variables discussed above. The drawback to consensus forecasts is that they are very specific to current events and difficult to replicate or adjust to changing circumstances. As such, they are of limited use when presenting policy-makers with alternative scenarios. A further advantage of model like this one is the opportunity for consistency-checking. USDA's ICEC sometimes adjusts its supply and demand outlook in response to prices, and this model provides an additional tool to aid in that process.

Future avenues for research relate to both world cotton markets and to the characteristics of USDA's supply and demand forecasts. While this study correctly identified some aspects of the structural change that has occurred in U.S. cotton markets since 1999, further examination of the sources of structural change and the channels through which it affects cotton prices are needed. In addition, forecasts based on this model will not only depend on the parameters of the model, but will also be conditional on the forecasts of supply and demand used to derive any particular forecast of price. Intuitively, early-season forecasts are less reliable than late-season forecasts, but further research can inform these intuitions, and identify key points in the season with respect to dynamics of forecast performance within the forecasting season. Furthermore, the accuracy of specific supply and demand variables and their potential contribution to the cotton price forecast errors should be examined with the goal of correcting for systematic errors in these forecasts.

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Table 1--Season-ending U.S. commodity program cotton stocks, 1974/75-2006/07.

Marketing year	CCC inventory	Collateral on outstanding loans	Inventory as share of use
	Thous. bales	Thous. bales	Percent
1974/75	0	235	2
1975/76	0	901	9
1976/77	0	110	1
1977/78	0	309	3
1978/79	1	1209	10
1979/80	0	614	5
1980/81	0	501	3
1981/82	1	626	5
1982/83	396	3643	31
1983/84	158	4267	40
1984/85	124	444	3
1985/86	775	1597	14
1986/87	69	5965	71
1987/88	5	2914	21
1988/89	92	3164	22
1989/90	27	4119	30
1990/91	1	430	3
1991/92	3	215	1
1992/93	13	297	2
1993/94	13	558	4
1994/95	0	179	1
1995/96	0	165	1
1996/97	0	312	2
1997/98	0	311	2
1998/99	6	61	0
1999/00	2	326	2
2000/01	5	68	0
2001/02	108	1460	9
2002/03	97	665	4
2003/04	0	668	3
2004/05	2	1371	7
2005/06	5	301	1
2006/07	51	1185	5

Sources: Stultz et al, Farm Service Agency (FSA) and ERS calcuations based on data from FSA and WASDE.

Table 2--Step 2 expenditures and price adjustment variable

Marketing year	Payments[1]	Payments/cotton use	Subsidy	Adjustment (λ_t)
	Mil. Dollars	dollars/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
1999/00	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.

Sources: Farm Services Agency, and ERS calculations based on data from the Farm Services Agency, WASDE, and Cotlook.

Table 3--Model data, 1974/75 through 2006/07

Marketing year	Price	Supply	S/U	China net imports	CCC	Foreign supply
			------Percent--------			
1974/75	-12.0	-10.8	114.1	-2.1	9.2	8.5
1975/76	11.6	-8.5	-41.6	-0.8	1.0	-4.3
1976/77	17.6	1.6	-26.4	-0.2	2.7	-6.3
1977/78	-23.5	21.2	82.2	1.6	10.1	2.6
1978/79	3.5	-6.5	-34.8	1.7	4.9	0.9
1979/80	-1.4	14.9	-37.6	3.3	3.2	-2.6
1980/81	9.3	-24.0	7.9	0.7	5.3	-0.1
1981/82	-32.4	29.9	179.9	-2.4	30.8	-0.6
1982/83	5.1	1.3	34.0	-3.0	43.5	2.1
1983/84	5.7	-15.8	-68.3	-2.6	4.7	-4.3
1984/85	-13.0	0.2	46.5	-1.9	14.6	18.8
1985/86	-5.6	11.4	227.0	-3.0	80.5	13.6
1986/87	-11.6	8.6	-68.7	-1.4	21.1	-1.3
1987/88	19.9	3.2	13.7	1.1	22.3	0.3
1988/89	-15.8	7.1	33.8	3.0	30.2	0.1
1989/90	10.2	-10.9	-69.2	2.6	2.8	-1.9
1990/91	1.8	-3.1	-24.2	1.0	1.3	0.5
1991/92	-19.0	8.6	82.5	-0.1	1.8	2.6
1992/93	-7.5	-1.0	24.3	-1.9	3.7	-3.4
1993/94	5.9	4.8	-30.0	-0.3	1.1	-5.1
1994/95	22.5	12.0	-35.3	4.8	0.8	-4.6
1995/96	3.0	-9.4	14.3	1.0	1.7	14.2
1996/97	-9.5	4.1	55.4	0.0	1.7	-0.6
1997/98	-10.5	3.8	-6.1	-1.7	0.3	3.3
1998/99	-9.1	-20.1	14.3	-3.4	2.3	2.3
1999/00	-28.2	13.9	-3.6	-2.5	0.4	5.8
2000/01	11.4	1.4	54.4	0.8	9.4	0.4
2001/02	-41.1	24.5	11.0	1.1	4.1	0.5
2002/03	43.0	-7.2	-29.3	2.5	4.0	-3.8
2003/04	38.2	-2.9	-35.6	7.6	6.8	-5.2
2004/05	-36.7	12.8	52.1	0.2	1.4	23.2
2005/06	14.1	11.0	-6.9	9.2	5.1	-6.3
2006/07	-1.7	-6.7	115.4	-2.7	5.1	7.5

Note: Price is percent change in the real U.S. season-average upland cotton farm price from year *t-1* to year *t* , Supply is percent change in U.S. supply from year *t-1* to year *t* , S/U is percent change in U.S. stocks-use-ratio from year *t-1* to year *t* , China net imports is the absolute change in China's net imports as a proportion of world demand from their average over the preceeding two years, and CCC is end of season stocks for year *t* of cotton either owned by USDA's Commodity Credit Corporation or remaining as collateral for the cotton loan program as proportion of demand for U.S. cotton that year. World supply is the percent change in global cotton supply (minus China's supply and plus China's next exports) from year *t-1* to year *t* .

Source: USDA National Agricultural Statistics Service, and *World Agricultural Supply and Demand Estimates* (various issues).

Table 4--Estimation results for cotton price model, 1974/75 - 2006/07

Variable or statistic	Coefficient	Std. Error	t-Statistic	Prob.
Constant	-0.026	0.026	-1.022	0.316
Supply	-0.949	0.190	-4.989	0.000
Stocks/use	-0.028	0.046	-0.597	0.556
China NI	3.060	0.828	3.697	0.001
CCC	0.372	0.162	2.299	0.030
Foreign supply	-0.867	0.356	-2.436	0.022
R-squared	0.688	--	--	--
Adjusted R-squared	0.630	--	--	--
Regression	--	0.118	--	--
Sum squared resid	0.376	--	--	--
Log likelihood	26.991	--	--	--
F-statistic	11.916	--	--	0.000
Mean dependent var	-0.017	0.194	--	--
Akaike info criterion	-1.272	--	--	--
Schwarz criterion	-1.000	--	--	--
Hannan-Quinn criter.	-1.181	--	--	--
Durbin-Watson stat	2.362	--	--	--

Note: Price is percent change in the real U.S. season-average upland cotton farm price from year t–1 to year t, Supply is percent change in U.S. supply from year t–1 to year t, S/U is percent change in U.S. stocks-use-ratio from year t–1 to year t, China net imports is the absolute change in China's net imports as a proportion of world demand from their average over the preceding two years, and CCC is end of season stocks for year t of cotton either owned by USDA's Commodity Credit Corporation or remaining as collateral for the cotton loan program as proportion of demand for U.S. cotton that year. Foreign supply is the percent change in world minus U.S. cotton supply (minus China's supply and plus China's net exports) from year t–1 to year t.

Table 5--Pearson Correlation Coefficients for Cotton Price Model, 1974/75 - 2006/07.

	Supply	Stocks/use	China NI	CCC	Foreign Supply
Supply	1.00	0.33	0.13	0.25	0.05
Stocks/use	0.33	1.00	-0.39*	0.60**	0.51**
China NI	0.13	-0.39*	1.00	-0.26	-0.39*
CCC	0.25	0.60**	-0.26	1.00	0.24
Foreign Supply	0.05	0.51**	-0.39*	0.24	1.00

Note: Supply is percent change in U.S. supply from year t–1 to year t, S/U is percent change in U.S. stocks-use-ratio from year t–1 to year t, China net imports is the absolute change in China's net imports as a proportion of world demand from their average over the preceding two years, and CCC is end of season stocks for year t of cotton either owned by USDA's Commodity Credit Corporation or remaining as collateral for the cotton loan program as proportion of demand for U.S. cotton that year. Foreign supply is the percent change in world minus U.S. cotton supply (minus China's supply and plus China's net exports) from year t–1 to year t. Number of observations is 33. One asterisk indicates significance at the 5% level (2-tailed), two asterisks indicate significance at the 1% level (2-tailed).

Table 6--Evaluation of price forecasting models, 2003/04-2006/07[1]

Model	Isengildina and MacDonald	Meyer[2]	WAOB[3]
Information set[4]	2008	2008	2008
Sample	1974-2002	1978-2002	1989-2002
	Cents/lb	Cents/lb	Cents/lb
Mean error (bias)[5]	2.1	2.0	-7.8
Root mean squared error (RMSE)	4.1	6.2	12.4
	Percent	Percent	Percent
Mean absolute percent error (MAPE)	7	8	16
Theil's U statistic	0.31	0.39	0.97
Granger-Newbold-Mariano statistic[6]	--	-0.97	-2.79
Diebold-Mariano statistic[7]	--	1.01	0.86

[1]Model parameters estimated with samples concluding no later than 2002/03.
[2]Meyer, 1998.
[3]Unpublished model developed by the World Agricultural Outlook Board.
[4]Information set used to estimate parameters. For each model, 2008 information is used to determine the values of the independent variables.

[5]For each year, $e_t = Y_t - F_t$, where Y_t is the actual realization of the price and F_t is the forecast. Therefore, $e_t < 0$ is an indication of upward bias. None of the models evaluated here had average forecast means that were significantly different from zero at either the 1%, 5%, or 10% level.
[6]GNM statistic testing difference between forecast accuracy of Isengildina and MacDonald forecast. None of the differences were significant at either the 1% or 5%. WAOB was significant at the 10% level.

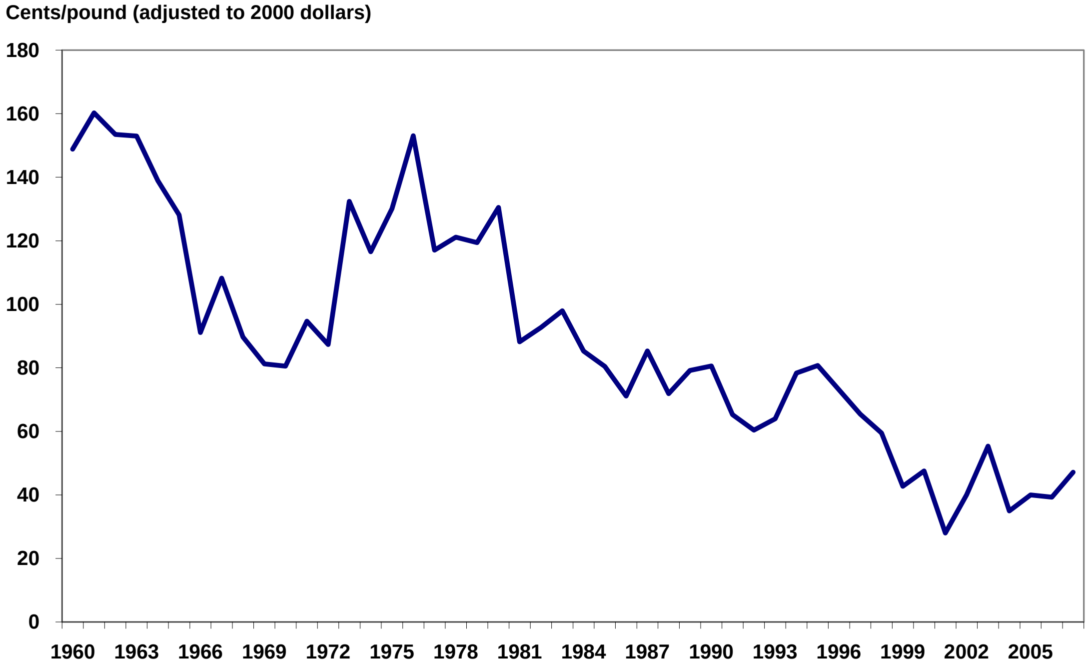
[7]DM statistic testing difference between forecast accuracy of Isengildina and MacDonald forecast. None of the differences were significant at either the 1%, 5% or 10% level.

Table 7--Parameter stability between samples and out-of-sample performance

Variable or statistic	1974/75-2006/07 Coefficient	1974/76-2002/03 Coefficient	Percent Difference
Constant	-0.026	-0.032	20
Supply	-0.949	-0.893	-6
Stocks/use	-0.028	-0.041	48
China NI	3.060	3.407	11
CCC	0.372	0.408	10
Foreign supply	-0.867	-0.830	-4
Accuracy: 2003/04-2007/08			
RMSE	7.221	7.499	4
MAPE	0.120	0.129	--
Theil's U statistic	0.606	0.581	--

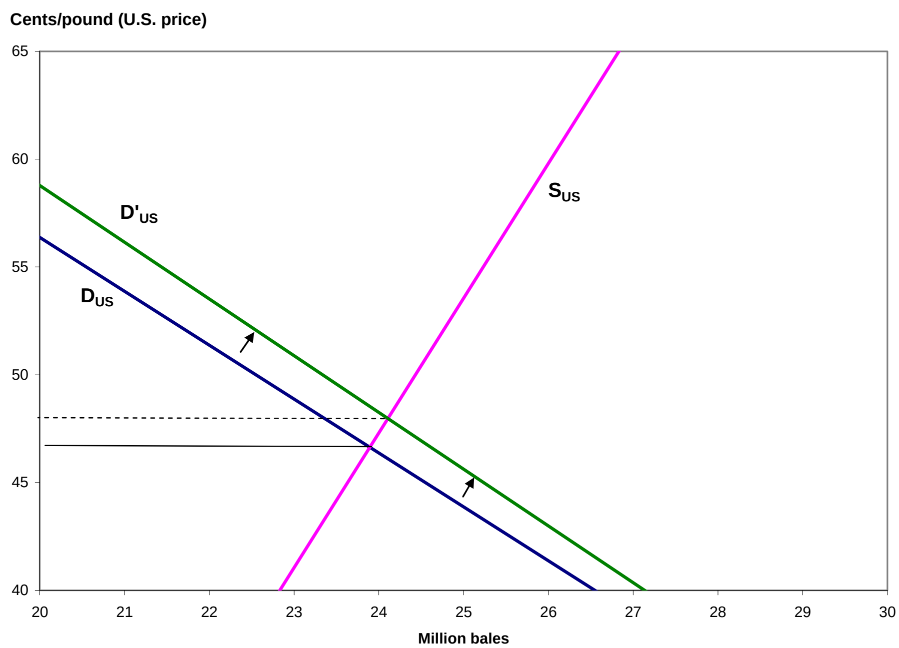
Note: Price is percent change in the real U.S. season-average upland cotton farm price from year t–1 to year t, Supply is percent change in U.S. supply from year t–1 to year t, S/U is percent in U.S. stocks-use-ratio from year t–1 to year t, China net imports is the absolute change in China's net imports as a proportion of world demand from their average over the preceding two years, and CCC is end of season stocks for year t of cotton either owned by USDA's Commodity Credit Corporation or remaining as collateral for the cotton loan program as proportion of demand for U.S. cotton that year. World supply is the percent change in global cotton supply (minus China's supply and plus China's next exports) from year t–1 to year t.

Figure 1: U.S. season-average farm price, upland cotton



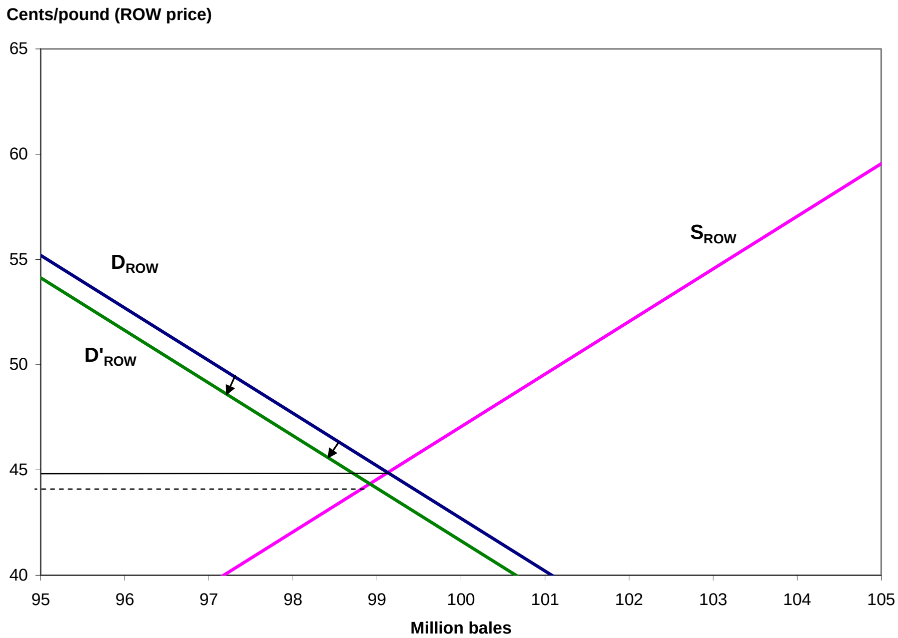
Source: ERS calcuations based on data from NASS and the U.S. Department of Commerce.

Figure 2--Impact of U.S. consumption subsidy on U.S.



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



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 4--Quandt Likelihood Ratio Test Results for Cotton Price Model, 1987/88-2006/07

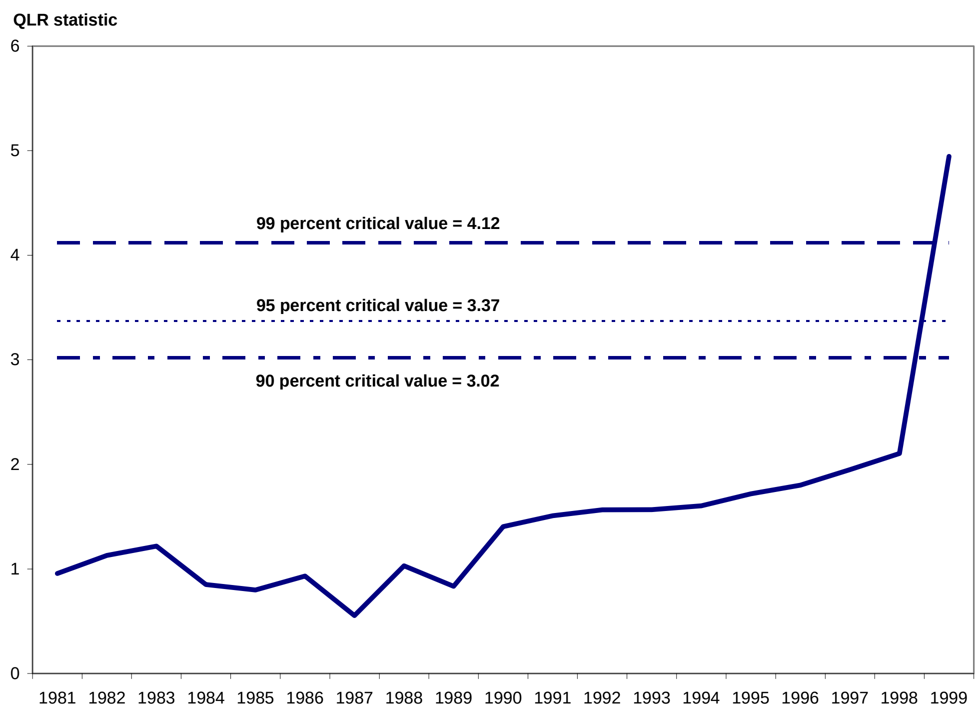


Figure 5--U.S. cotton exports and consumption

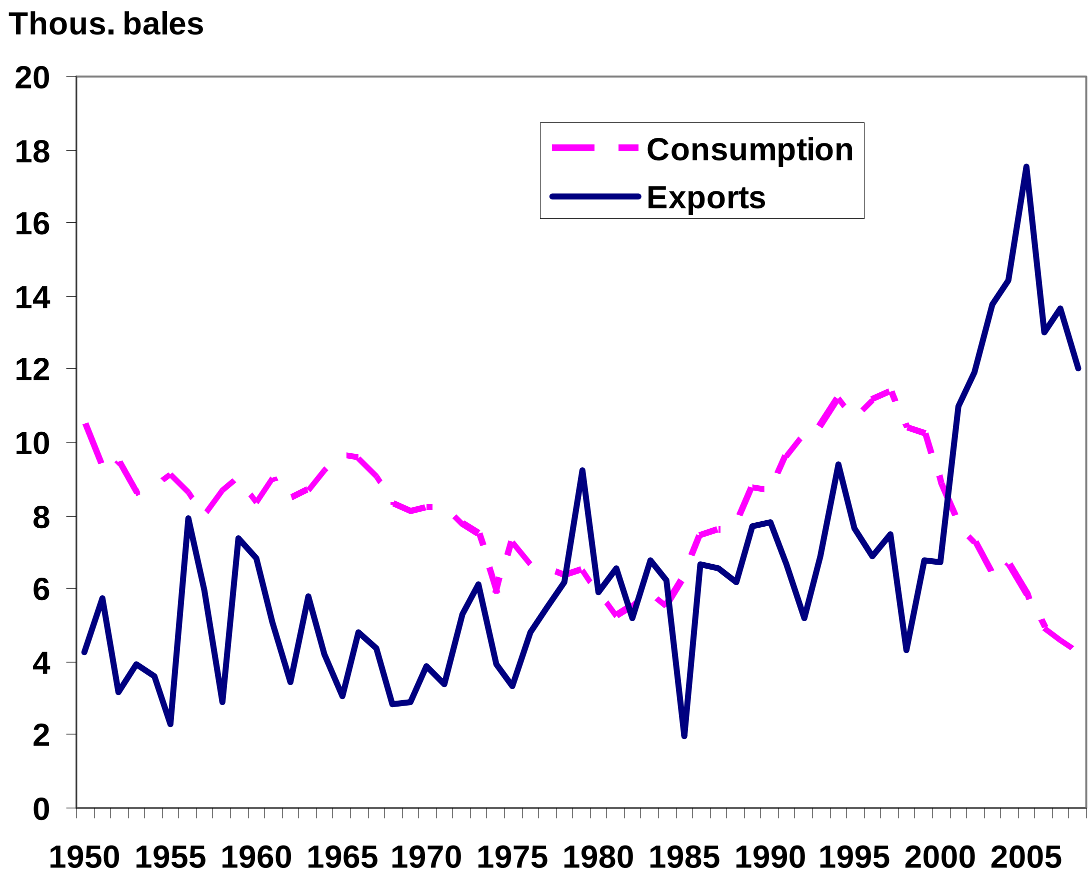


Figure 6--Actual and predicted U.S. upland cotton farm price

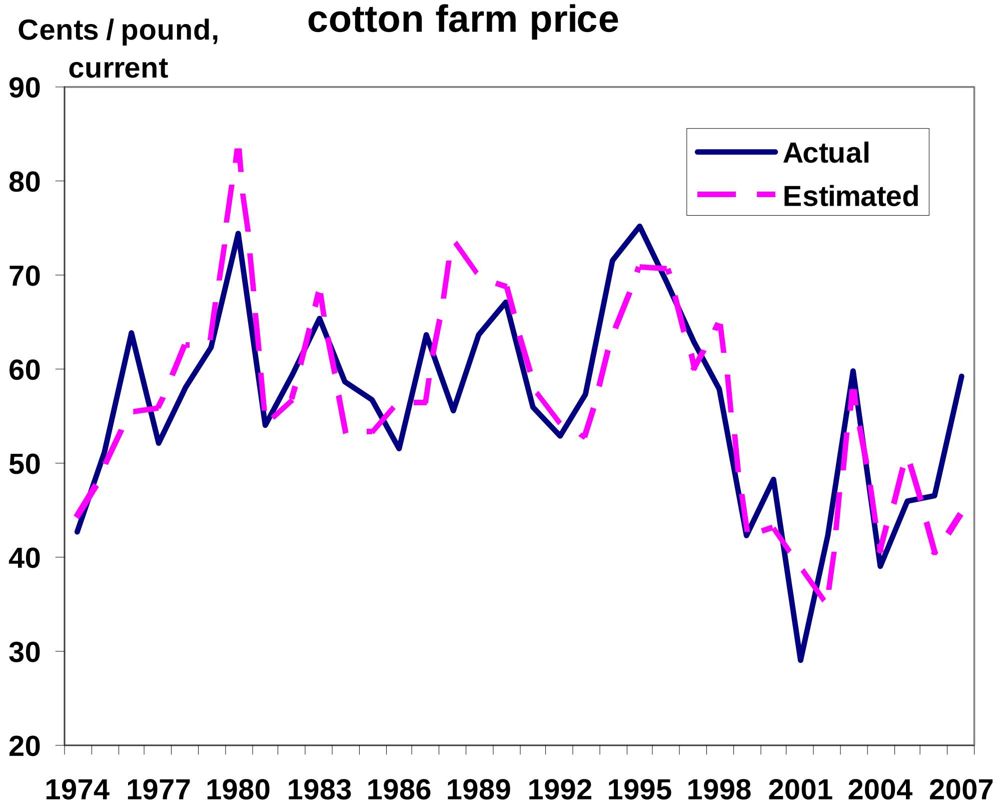


Figure 7--Out-of-sample performance of proposed model relative to alternative models.

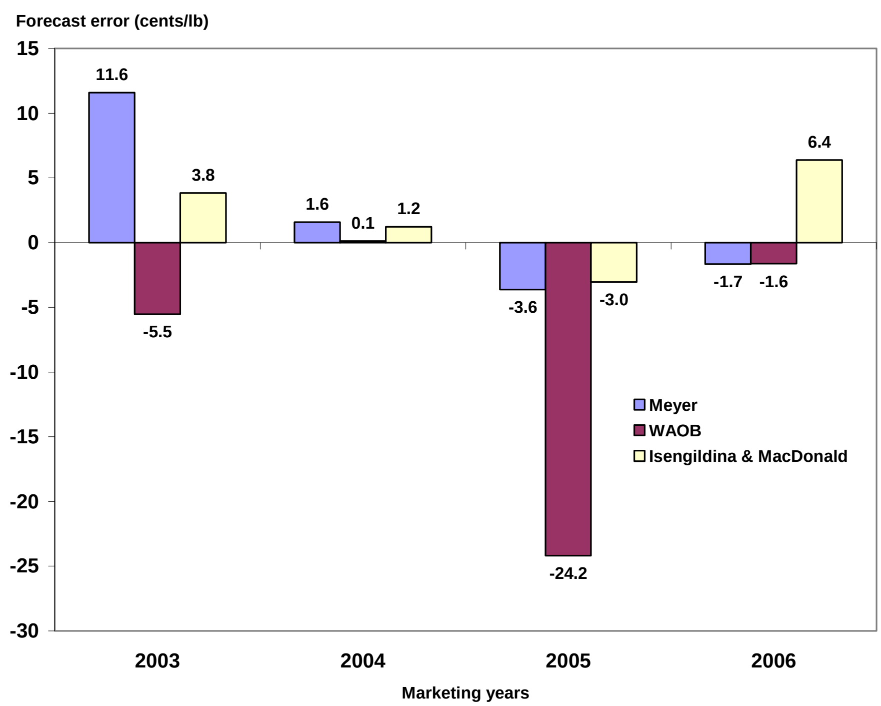


Figure 8--December ICE cotton contracts' basis, 2003-2008