Cotton Price Forecasting and Structural Change

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Abstract

Agricultural prices have long been forecast with reduced-form models including ending stocks as an independent variable. In recent years, cotton prices have been persistently low compared with the other agricultural products that compete with cotton for land and other inputs. Furthermore, the cotton price forecasting models used by a number of entities have chronically realized positive errors—persistently forecasting prices too high. This paper reviews some general principles behind short-term agricultural price forecasting, discusses some of the issues specific to specifying cotton price forecasting models, and compares the forecasting performance of an number of alternative specifications. The discussion and results are intended to lay the basis for developing new models that account for structural changes in world cotton markets.

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 market place, and changing tastes and technology. Forecasts of agricultural prices are important to both private and public policy-makers, as well producers and consumers of agricultural products, and certain models have come into widespread use in government, academia, industry, and international agencies. Cotton prices are an important concern for cotton farmers, textile mills, and shippers, but there are several factors peculiar to cotton. One is that USDA is legally prohibited from forecasting cotton prices. Another is the long-standing lack of reliable economic information available from China, the country that has come to dominate world consumption and trade in cotton in recent years. Finally, cotton prices have distinctly diverged from relatively long-standing relative price relationships in recent years.

While corn, wheat, soybean, and rice prices have all returned to, or surpassed, the nominal levels they achieved during the 1990's, cotton prices during 2005/06 were about 20 percent below these earlier levels. Furthermore, the economic models developed by USDA and other entities to forecast cotton prices have persistently failed to anticipate the degree to which cotton prices have been below past levels and the levels of competing crops. As first step to revising these models, a careful examination of alternative model specifications is appropriate.

Agricultural Price Forecasting

The world economy is increasingly integrated, and unprocessed agricultural commodities have long been at the forefront of this integration. This suggests that the relationship between U.S. and world prices for cotton might be described by the "Law of One Price" (LOP). At its simplest, the LOP states that the price of a good in various countries is exactly the same after adjusting for the different currencies in these countries. The weak form of the LOP acknowledges that even when two countries have and integrated market for a good, transportation costs and policy differences mean that the good's price in the two countries can be constantly different. The result is that the currency-adjusted prices in the two countries are not necessarily at equal levels, but do adjust to market conditions together. If this were true for cotton prices, it would arguably be an arbitrary choice whether to forecast the price of cotton within the United States or a foreign or world price stated in U.S. dollars.

The price transmission elasticity between world cotton prices (Cotlook's A-Index) and U.S. cotton prices (the National Agricultural Statistical Service's season-average farm price) during 1996/97-2005/06 was not significantly different from 1 at the 5 percent level, so it is appropriate to consider the U.S. cotton market integrated with the world cotton market. However, this relationship did not hold in every year. In 1998/99 U.S. and world prices differed by 19 percent, compared with an average absolute difference in the other years of 3 percent (with a maximum difference of 7 percent). Under certain circumstances, U.S. and world prices can respond differently to developments in cotton supply and demand. Furthermore, the U.S. Step 2 program created a wedge between U.S. and world prices in some years. This program has been terminated by the United States to reach compliance with the findings of a World Trade Organization (WTO) Dispute Settlement Panel. Given this information it is clear there is a need to forecast world and U.S. prices separately. This analysis will concentrate of forecasting world prices (see Meyer, 1998, for discussion of forecasting U.S. cotton prices).

The U.S. cotton market's integration with world cotton markets is effected through trade. This would suggest that prices could be forecast on the basis of either expected U.S. supply and demand or world supply and demand. Trade between the U.S. and the rest of the world would be part of the market equilibrium that determines prices in a given year, so production and consumption shocks outside the United States would be reflected in U.S. stocks as U.S. exports adjusted to these shocks. Strictly speaking however, this equilibrium can be achieved through either actual trade or potential trade. At various times, it has been appropriate that cotton ultimately destined for consumption outside the Untied States be stored either within the United States or in other countries for relatively extended periods to take advantage certain market conditions or government policies. These conditions have changed from year to year, so U.S. and foreign stocks have fluctuated with respect to each other due to circumstances that may not have had significant impact on the level of world prices in these years. This analysis will use world supply and demand to forecast prices, given that the price in question is also a world price.

While the forecasted price is a world price, and the independent variables are also at the global level, the structure of the models examined here is analogous to the structure used by USDA to forecast U.S. domestic prices (e.g. Meyer, Westcott and Hoffman, Plato and Chambers, and Chambers). One difference from these earlier models is the inclusion of an exchange rate variable. While the A-Index is widely quoted in U.S. dollar terms, cotton and cotton-based products are bought and sold throughout the world with prices stated in other currencies. Therefore, the model is specified with supply and demand a function of the A-Index in U.S. dollar terms times an exchange rate index:

$P \quad A \quad \text{Index}$	(Northern Europe cotton price in U.S. dollars)
$e \quad \text{U.S. exchange rate index}$	(foreign currency units per U.S. dollar)
$P_W \quad Pe$	
$D_W \quad f(P_W, P_{W,t\ 1}, Z_D)$	demand function
$S_W \quad g(P_{W,t\ 1}, Z_S)$	supply function
$K_W \quad h(P_W, Z_K)$	stocks function
$0 \quad S_W \quad D_W \quad K_W$	equilibrium condition
$\mathrm{P} \quad \mathrm{h}^{-1}(K_W, e, Z_K)$	implicit price function

Stocks as a share of use is a variant of this model that is typically applied to forecasting, and is the variant used in this analysis.

Short-term price forecasting can also be accomplished by extending estimated trends and more sophisticated univariate analysis. Alternatively, published futures prices can be used to derive forecasts of future farm and spot prices by forecasting future basis levels to adjust futures prices. While these approaches have their merits, variations of the reduced-form structural approach illustrated above have been preferred by many forecasters. Price forecasting often occurs in the context of expected weather, policy, and demand stocks which may cause prices to diverge from past trends and that may not have been reflected in current futures prices.

Issues Specific to World Cotton Markets

Commodities are differentiated by their physical characteristics, but also by the structure of their markets and role of different institutions in these markets. Two recent developments in world cotton markets suggest technical change may have altered the relationship between cotton prices and the supply and demand for cotton.

One is the widespread adoption of genetically modified (GM) cotton varieties around the world. Starting with the United States late in the 1990's, GM cotton spread quickly to Australia and China. After being adopted in Mexico, South Africa, and to some extent in Argentina, GM cotton has in recent years come to account for 50 to 60 percent of cotton planted in India. With GM cotton now widely adopted in the third largest cotton producing country (China and the United States are the first and second largest), GM cotton came to account of 28 percent of world cotton area, according to the International Service for the Acquisition of Agri-Biotech Applications. Interestingly, soybeans surpass cotton in the global area share attributable to GM varieties (59 percent), but in another important respect cotton has surpassed soybeans, as well as other crops.

GM-cotton adoption is a yield-enhancing development in developing countries due to improved pest management. In the United States, developments like the continued spread of the boll-weevil eradication program and the development of new management techniques has also led to significant yield growth. As a result, a weighted average of the yield indices of the 10 largest cotton producers in the world has realized 31 percent growth since 1997. By comparison, a similar measure of soybean and corn yields grew only 13 percent (Table 1).

It is plausible that the widespread adoption of GM cotton in developing countries, and further technical change in the United States, has lowered the cost of cotton production. This would be consistent with both the behavior of cotton prices and with the persistent over-estimates produced by price forecasting models. It is also consistent with economic theory which indicates that in the absence of market power the price of goods reach equilibrium at their marginal cost of production. Note that this is just a statement of a hypothesis and this study does not address the testing of this hypothesis. In March 2006, the International Cotton Advisory Committee (ICAC) published a review of their forecasting model's performance, and offered other reasons for its over-estimates. The purpose of this study is to explore the best way to devise new cotton price forecasting models in the face of recent changes rather than to determine why older models are no longer adequate.

The ICAC cited changes in China's stockholding behavior as a potential reason for the persistent price forecasting errors. China's role in world cotton markets differs from its role in other commodity markets. While both cotton and soybeans stand out among the major U.S. field crops for the large role international trade plays in consumption, cotton differs from soybeans in the proportion of world consumption accounted for by China. Trade is extremely important to world cotton markets, with 36 percent of world cotton traded across international borders before being consumed. This compares with 13 percent for beef and 21 percent for wheat, but only 8 percent for rice. Soybeans also have about 35 percent of all consumption first crossing international borders.

Interestingly, cotton and soybeans are also similar in that about 15 percent of total world consumption is accounted for by China's imports. However, there are two important differences between these two commodities. One is that China's trade regime is more liberal for soybeans than for cotton, and the other is that China's share of world consumption is much larger for cotton than for soybeans. In 2005/06, about 40 percent of the world's cotton was consumed in China, about twice China's share of world soybean consumption.

Specifying Cotton Price Models

The model $P = h^{-1} (K_W, e, Z_K)$ includes Z_K, exogenous variables affecting demand for stocks. One variable included in a number of cotton price forecasting models is China's net cotton imports. China was until recently a relatively closed economy. An economy's openness is typically equated to the proportion of its economic activity linked to the rest of the world. The ratio of trade to economic activity is a typical metric of these links. Through the 1980's and early 1990's, China's economy was closed in this respect, but was also closed with respect to the transmission of information.

Economic data that was widely disseminated in other countries was officially treated as a state secret in China. This secrecy, combined with other factors, made China's demand for foreign cotton a key variable in the determination of world cotton prices for a number of years. One factor was China's centrally planned economy, which reacted slowly to trends in China's agricultural production. Another factor was China's large population, and the role of textile exports in China's economy during the 1980's. This demand for domestic and exported clothing kept China's demand for cotton relatively stable, while fluctuating production resulted in periodic surpluses and shortages. The secrecy surrounding China's economy meant that world cotton markets had limited information about the likely magnitude or duration of the resulting large swings between net exports and net imports.

Between 1980 and 2000, there was a 74 percent correlation between China's net cotton trade and the A-Index. However, in recent years, China has come to dominate world cotton markets to such an extent that it is difficult to regard any aspect of its behavior as exogenous. China is expected to be a large net importer for the foreseeable future, and the surge in China's imports has coincided with weakness in world cotton prices in recent years. The impact of including or excluding China's net trade in the specification of cotton forecasting models will be examined below.

Another important model specification variation in world cotton price forecasting models concerns the measurement of world stocks. As noted earlier, limitations on information available from China are an issue in world price determination. For many years, the magnitude of China's cotton stocks was regarded by the government there as a a state secret. In recent years, the official desire for secrecy has diminished, and government agencies in China participate in the publication of estimates of China's cotton stocks. However, much uncertainty remains to this date about the supply and demand for cotton in China, and an estimate of historical relationships probably will rely on data from years when China's government suppressed information about its domestic cotton stocks. There, one alternative to a measure of world cotton stocks for K_W in $P = h^{-1}(K_W, e, Z_K)$ is world stocks only outside of China.

Stocks variables in price forecasting models are typically expressed ass a share of consumption. If China's stocks are excluded from the measurement of world stocks, then it seems appropriate that China's consumption be excluded from the world consumption estimate used in the stocks/use ratio. Given the absence of official estimates from China of cotton consumption there, the reasonableness of this approach seems even greater. However, China's cotton consumption is now estimated to account for 40 percent of world consumption. Therefore, excluding China's consumption from a global estimate overlooks some of the most important developments in world cotton markets. The impact of including China's consumption from the world consumption estimates used in ratios of stocks-to-use and use-to-stocks will be examined below.

Another model specification variation that will be examined is the effect of measuring stocks directly or in inverse form. Price levels and ending stock levels are inversely related, which is a non-linear relationship. While it is not widely utilized (MacDonald is one example), use-to-stocks is an alternative expression of K_W that will be examined below.

Finally, trends are often included in models to account for unobservable variables with trends, like technical change. Inflation-adjusted cotton prices have a downward trend, as is the case for most unprocessed commodities, presumably reflecting long-run changes that have reduced the cost of cotton production. Given that cotton prices are hypothesized to have fallen in both the long run and the short run due to technical change, it seems reasonable that a cotton price forecasting model might include a trend among its exogenous variables.

Results

A range of alternative cotton price forecasting models were specified, estimated, and compared for recent forecast accuracy. Models were specified with six alternative measures of ending stocks, K_W:

SUW,	World stocks-to-use
SUWxC,	World minus China stocks divided by world minus China consumption
SUWCC,	World minus China stocks divided by world consumption
USW,	World use-to-stocks
USWxC,	World minus China consumption divided by world minus China stocks
SUWCC,	World consumption divided by world minus China stocks

Models with each alternative K_W was also specified with and without two exogenous variables, Z_K:

NIM,	China's net cotton imports
TREND,	a linear trend.

A cotton-specific exchange rate was included as an exogenous variable in all the models examined (RXR). With all possible exogenous variables the full model examined here was,

$$P = h^{-1}(K_W, RXR, NIM, TREND).$$

After examining the time series properties of the variables, the models were estimated with ordinary least squares (OLS) with 1986-2002 data. Forecasts were generated for 2003-05, and the mean absolute percent errors (MAPE) of the various models compared. Two additional versions of each model were also estimated: one version with 1986-1993 data, and another with 1993-2002 data. The MAPE's of these model's forecasts were compared with each other and the models estimated over the full sample to assess the variation in accuracy over time.

Examination of the time series properties of the A-Index and the independent variables used to forecast it indicates that most of these variables are non-stationary (the null hypothesis of non-stationarity cannot be rejected in the Augmented Dickey-Fuller test), but are stationary in first differences (the data generating processes are generally I(1)). (Table 2) The A-Index is trend stationary at the 10 percent significance level, and USWCC is trend stationary at the 5 percent level. The remaining variants of K_W are not trend stationary.

The only variant of K_W among the variables that are not I(1) are SUW and USW. Interestingly neither RXR nor NIM were I(1), but were I(2). Neither SUW nor USW were I(2). The heterogeneity of the data generating process of these variables could become an issue when developing models based on estimates of the cointegrating vectors and dynamic adjustment parameters between the exogenous variables, prices, and stocks.

The variants of K_W producing the least accurate forecasts were SUW and USW (based on average accuracy across the full set of possible exogenous variables and sample time periods) (Tables 3-6). The most accurate over the full sample (1986-2002) were USWxC and SUWxC, but the most accurate over the recent sample (1993-2002) were USWCC and SUWCC. With respect to the exogenous variables, the least accurate specification estimated over the full sample was to include both NIM and TREND. Generally speaking, accuracy was improved by excluding exogenous variables.

The most accurate specification over the entire sample was

$P = h^{-1}$ (USWCC, RXR).

And the least accurate was

$P = h^{-1}$ (SUW, RXR, NIM, TREND).

The most accurate estimates of all the models were those estimated with 1993-2002 data where K_W equals either USWxC or SUWxC and NIM is excluded. The inclusion of TREND has little impact on the accuracy of these models. During the earlier time period, the greatest accuracy was achieved by excluding TREND, including NIM, and using any variant of world minus China stocks/use or use/stocks. Interestingly, over the full sample, including TREND and excluding NIM reverses the relative accuracy of USWxC and USW: USW and SUW are the most accurate while USWxC and SUWxC are the least accurate..

Conclusions

A comparison of the forecast accuracy of a wide variety of cotton price forecasting models indicates that the preferred world stock variable includes an adjustment to exclude China to some degree. It is difficult to rank the different ways of treating China's consumption in the estimate of K_W based on these results. Given the dynamic nature of world cotton markets, it might seem preferable to emphasize accuracy using more data from a more recent sample, which would suggest the preferred model is $P = h^{-1}$ (USWxC, RXR). However, the difference in accuracy between models with WxC and WCC is not great.. Similarly, this analysis indicates that neither US nor SU are particularly superior to one another. Further testing of more sophisticated models with stocks estimates with or without China's consumption and in either SU or US form seems appropriate. Models with unadjusted stocks estimates should probably not be pursued, and the usefulness of including China's trade or a trend in price forecasting models seems questionable under current circumstances. China's trade was a useful explanatory variable during the 1990's, but this no longer seems to be the case.

References

Chambers, William (2004), *Forecasting Feed Grain Prices in a Changing Environment*, FDS-04F-01, Economic Research Service, U.S. Department of Agriculture.

MacDonald, Stephen (1997), "Forecasting World Cotton Prices," *The Ninth Federal Forecasters Conference—Papers and Proceedings*, National Center for Educational Statistics, U.S. Department of Education.

Meyer, Leslie (1998), "Factors Affecting the U.S. Farm Price of Upland Cotton," *Cotton and Wool Situation and Outlook Yearbook*, CWS-1998, Economic Research Service, U.S. Department of Agriculture.

Plato, G., and W. Chambers, (2004). *How Does Structural Change in the Global Soybean Market Affect the U.S. Price?* OCS-04D-01, Economic Research Service, U.S. Department of Agriculture.

Secretariat of the ICAC, (2006), "Update on the ICAC Price Model," *Cotton: Review of the World Situation*, 59(4): 6-8.

Westcott, P., and L. Hoffman, (1999). *Price Determination for Corn and Wheat: The Role of Market Factors and Government Programs*, TB-1878, Economic Research Service, U.S. Department of Agriculture.

Table 1--Trends in world field crop exporter yields[1]: cotton strongest

	Wheat	Corn	Soybeans	Rice	Cotton
	Index: 1990s average = 100				
Average, 2004-06	109	119	114	113	135

Source: *World Agricultural Supply and Demand Estimates*.
[1]Production-weighted averages of yield indices for top three 2006 exporters.

Table 2--Rejection of H_0 of non-stationarity (1985-2005 sample)

Variable	ADF Test statistic	Prob. value	Constant	Trend	Lags
Real A-Index	3.316	0.09	Yes	Yes	0
Real A-Index	1.351	0.58	Yes	No	0
USW	1.448	0.81	Yes	Yes	2
USWCC	3.688	0.05	Yes	Yes	2
USWCC	1.230	0.64	Yes	No	2
SUW	1.214	0.88	Yes	Yes	2
SUWCC	4.064	0.03	Yes	Yes	2
SUWCC	1.170	0.66	Yes	No	2
NIM	1.509	0.79	Yes	Yes	2
RXR	1.645	0.73	Yes	Yes	2
dNIM	1.306	0.85	Yes	Yes	1
dRXR	3.076	0.14	Yes	Yes	0
ddRXR	3.833	0.05	Yes	Yes	4

Source: Estimated with Eviews 5.0

Table 3--Forecast errors by stocks variable and China trade assumption

Stocks variable	China trade	Error by sample (MAPE): Complete	1990's	2000's
		Percent	Percent	Percent
SUW	No	56	27	35
SUW	Yes	51	23	81
SUWxC	No	61	15	8
SUWxC	Yes	50	11	59
SUWCC	No	22	17	12
SUWCC	Yes	25	11	67
USW	No	51	21	35
USW	Yes	47	18	88
USWxC	No	37	15	6
USWxC	Yes	35	11	60
USWCC	No	15	17	12
USWCC	Yes	22	12	66

Source: Forecast errors in 2003-5 or 1993-5.

Table 4--Forecast errors by stocks variable and China trade assumption (trend included)

Stocks variable	China trade	Error by sample (MAPE): Complete	1990's	2000's
		Percent	Percent	Percent
SUW	No	13	40	57
SUW	Yes	88	38	67
SUWxC	No	48	37	7
SUWxC	Yes	54	42	56
SUWCC	No	21	39	12
SUWCC	Yes	64	43	64
USW	No	16	40	52
USW	Yes	87	39	60
USWxC	No	38	37	6
USWxC	Yes	49	41	60
USWCC	No	18	39	20
USWCC	Yes	63	43	65

Source: Forecast errors in 2003-5 or 1993-5.

Table 5--Average MAPE by stocks variable

Stocks variable	Error by sample (MAPE): Complete	1990's	2000's
	Percent	Percent	Percent
SUW	52	32	60
SUWxC	53	26	32
SUWCC	33	28	39
USW	50	30	58
USWxC	40	26	33
USWCC	30	28	41

Table 6--Average MAPE for models by trade and trend

Variable	Error by sample (MAPE): Complete	1990's	2000's
	Percent	Percent	Percent
China trade	53	28	66
No trade	33	29	22
Trend	47	40	44
No trend	39	17	44
Both	67	41	62
Neither	40	19	18