Response of Cotton to Oil Price Shocks

Maria Mutuc
Cotton Economics Research Institute
Department of Agricultural and Applied Economics
Texas Tech University
Lubbock, TX 79409-2132
Email: maria.mutuc@ttu.edu

Suwen Pan
Cotton Economic Research Institute
Department of Agricultural and Applied Economics
Texas Tech University
Lubbock, TX 79409-2132
Email: s.pan@ttu.edu

Darren Hudson
Cotton Economic Research Institute
Department of Agricultural and Applied Economics
Texas Tech University
Lubbock, TX 79409-2132
Email: darren.hudson@ttu.edu

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ABSTRACT

This paper shows that the response of cotton prices in the U.S. to fluctuations in oil prices in the international market may differ greatly depending on whether the increase is driven by demand or supply shocks in the crude oil market. In the long-run, around 3 percent of the variability in cotton prices can be attributed to shocks to global demand for industrial commodities while none can be traced to oil supply shocks.

Keywords: Cotton, oil price, demand shocks, supply shocks, structural vector autoregression

JEL Classification: Q11; Q41

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1. Introduction

Oil prices affect cotton prices in two channels. The first channel, more pronounced in recent years, is through the substitutability in consumption between oil and biofuels such as ethanol, methanol, and biodiesel. With the surge in crude oil prices to historically high levels of, initially US$60 per barrel in 2005, to $128 per barrel in 2008, the demand for ethanol has significantly strengthened. This, in turn, fueled the derived demand for cellulosic materials such as corn, among others, from which biofuels are created. In the U.S., as the ethanol industry absorbed a significant share of corn crop, corn prices have risen in recent years. Higher corn prices have provided farmers the incentive to switch acreage from competing crops to corn. One of these competing crops is cotton, the acreage for which has declined by as much as 45% from 2005-2008 (from 5.586 million hectares to 3.063 million hectares in 2008/09), the period following the passage of the Energy Policy Act of 2005 that contains a new Renewable Fuel Standard (RFS). The RFS ensures that gasoline marketed in the United States contains a specific minimum amount of renewable fuel. Between 2006 and 2012, the RFS is slated to rise from 4.0 to 7.5 billion gallons per year (Baker and Zahniser, 2006). While there is no direct linkage and evidence on the extent of cotton acreage diverted to corn, the timing of sustained acreage reductions coincided with the surge in corn demand. Through this channel, higher oil prices reduce cotton supply via acreage reductions (limited by the extent of production substitutability between cotton and corn), *ceteris paribus*. This, in turn, results in higher cotton prices. At the same time, higher oil prices lead to higher cost of cotton production. Most cotton growers are painfully aware that the 2008 crop was an expensive one to produce due, at least in part, to crude oil prices above $128 a barrel that sent retail gasoline and diesel prices to soar.

The second channel involves the use of cotton in the textile sector and its substitutability with polyester in textile manufacturing. Higher oil prices translate to more expensive energy and electricity which raises the cost of polyester fiber production – a sector heavily dependent on chemical derivatives of crude oil for inputs. A relatively more expensive polyester fiber props up the demand for cotton. In fact, the cross-price elasticity between cotton and polyester is positive in most countries; currently, several domestic price policies account for the substitutability between cotton and polyester: Chinese internal policies and import controls have generally supported cotton prices in the range of 120-130 percent of polyester prices; in India, cotton and polyester prices are roughly at the 1-to-1 price ratio; in Pakistan, cotton prices are around 80 to 90 percent of polyester prices (Laws, 2009). In the U.S., Pan, Mohanty, and Fadiga (2007) found that polyester prices and cotton prices Granger-cause each other.

There is no consensus in the literature on the nature of the relationship between cotton and crude oil prices. While some studies found the relationship between cotton and crude oil prices to be weak (Fadiga and Misra 2007; Plastina, 2010), others attest to the existence of a significant relationship. Baffes and Gohou (2003) examined the price linkages among polyester, cotton and crude oil based on monthly data between 1980 and 2002. They found a strong co-movement between cotton and polyester prices. In the same study, crude oil prices had a stronger effect on polyester prices than on cotton prices; also price shocks originating in the polyester market were transmitted at a much faster speed to the cotton market than *vice-versa*. Baffes (2007) analyzed the contemporaneous relationship between oil spot prices and the spot prices of other commodities with annual data for 1960-2005. The elasticity of cotton price with respect to oil price is found to be 14%, and the elasticity with respect to inflation 89%. Harri, Nalley, and Hudson (2009) also found that corn, cotton, and soybeans prices have strong relationships with oil prices. However, the question of whether these relationships between commodity prices and oil prices are due to crude oil supply shocks or demand shocks is seldom discussed. This question, when answered, will enable policymakers to appropriately and more accurately account for the incidence of upward and downward oil price movements and their effects on the cotton sector, among others.

Therefore, the objective of this study is to understand the response of cotton prices in the U.S. to crude oil price changes in the world market. Specifically, we will examine whether the transmission of the fluctuations in oil prices to cotton prices is driven by crude oil supply shocks or demand shocks. The information generated from this article would be useful for further analysis of various welfare studies and income stabilization policies for cotton farmers in episodes of oil price shocks. This research also contributes to recent studies that investigate the effects of oil prices on specific agricultural commodities such as corn, sugar, among others (Rapsomanikis and Hallam, 2006; Campiche et al., 2007; Yu, Bessler, and Fuller, 2006; Zhang and Reed, 2008; Harri, Nalley, and Hudson).

2. Data and Methods

2.1 Data

Monthly data from 1976-2008 for crude oil prices and cotton prices for the U.S. are used in the estimation. These are correspondingly sourced from the Energy Information Administration (EIA) and the National Cotton Council (NCC).

The series is obtained for the period 1975.1 to 2008.2 based on the average price of landed mill sales of cotton from the website of the National Cotton Council. Mill delivered prices are provided by the Market News Branch of USDA's Agricultural Marketing Service (AMS) based on daily cotton sales transactions in four regions of the U.S. The series is deflated with U.S. Consumer Price Index (CPI) to come up with the real price of cotton.

The oil price series is based on the refiner acquisition cost of imported crude oil for the period 1975.1 to 2009.8 from the U.S. Department of Energy and is deflated using the U.S. CPI. The levels of crude oil production in thousands of barrels per month for both OPEC and non-OPEC countries were retrieved from the U.S. Energy Information Administration for the period 1975.1 to 2009.4.

The index of global real economic activity is from Kilian (2009) based on representative single voyage freight rates collected by Drewry Shipping Consultants Ltd. for various bulk dry cargoes including grain, oilseeds, coal, iron ore, fertilizer and scrap metal. In constructing the index, Kilian used these rates provided for different commodities, routes and ship sizes quoted in U.S. dollars per metric ton. He then took simple averages of the freight rates and eliminated the different fixed effects for different routes, commodities and ship sizes by first computing the period-to-period growth rates for each series and then taking the equal-weighted average of these growth rates, and cumulated the average growth rate and indexing it January of 1968 (equal to unity). The indexed series is deflated with the U.S. CPI to come up with a real freight index series. Since Kilian was interested in the cyclical variation in ocean freight rates the real freight index series was linearly detrended and the deviations of the real freight rates from their long-run trend are calculated. The resulting variable was used as index of global real economic activity. The link to the data is http://www- personal.umich.edu/~lkilian/reaupdate.

2.2 Methods

Following Kilian and Park (2009), we adopt a structural vector autoregressive (SVAR) model that relates U.S. cotton prices to measures of demand and supply shocks in the global crude oil market. Specifically, we estimate a SVAR model based on monthly data for the vector time series Z_t, consisting of the percent change in global oil production, the measure of real activity in global industry commodity markets, the real price of crude oil, and the U.S. cotton price. The structural representation of this model is

(1) $$A_0 Z_t = \alpha + \sum_{i=1}^{T} A_i Z_{t-i} + \varepsilon_t$$

where ε_t denotes the vector of serially and mutually uncorrelated structural innovations. Let e_t denote the reduced form VAR innovations such that $e_t = A_0^{-1}\varepsilon_t$. The structural innovations are derived from the reduced form innovations by imposing exclusion restrictions on A_0^{-1}. The model imposes a block-recursive structure on the contemporaneous relationship between the reduced-form disturbances and the underlying structural disturbances. The first block constitutes a model of the global crude oil market. The second block consists of U.S. real cotton price.

In the oil market block, there are three structural shocks that contribute to the real price of oil: an oil supply shock, ε_{1t}, an aggregate demand shock, ε_{2t}, and an oil market specific demand shock, ε_{3t} (precautionary demand for crude oil as termed by Kilian and Park (2009)). In the cotton market block, there is only one structural innovation that contributes to the real cotton price: an innovation not driven by global oil market ε_{4t}.

Therefore, equation (1) can be re-written as follows:

(2) $$e_t = \begin{bmatrix} e_{1t} \\ e_{2t} \\ e_{3t} \\ e_{4t} \end{bmatrix} = \begin{bmatrix} a_{11} & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 \\ a_{31} & a_{22} & a_{33} & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \end{pmatrix}$$

The model structure implies that global crude oil production, global real activity and the real price of oil are predetermined with respect to U.S. real cotton price. U.S. real cotton price is allowed to respond to all three oil demand and supply shocks while ε_{4t} does not affect global oil market at least within a given month.

3. Results and Discussion

Table 1 presents the results of the Augmented Dickey-Fuller (ADF) and Kwiatkowski, Philipps, Schmidt & Shin (KPSS) (1992) unit root tests for each price series. Varying lag orders were used in the ADF and KPSS tests as suggested by the usual model selection criteria (i.e., Akaike Information Criterion (AIC), Hannan-Quinn Criterion (HQ), and Schwarz Criterion (SC)); deterministic terms were allowed to vary from solely a constant to a constant with time trend. While the null hypothesis for the ADF is one of nonstationarity, the KPSS tests the null that the data generating process (DGP) is stationary so that if a series is I(0), the ADF test should reject the nonstationary null hypothesis, whereas the KPSS should not reject its null hypothesis. The hypothesis tests for the ADF are based on a comparison of calculated statistics with the critical values from Davidson and MacKinnon (1993) statistics while the KPSS tests are based on critical values from Kwiatkowski et al. (1992). The conclusions from the ADF tests are quite clear: At both the 5% and 10% significance levels, unit roots cannot be rejected for both oil and cotton prices in levels (where the deterministic term include only a constant) but are rejected for both price series in their first differences (in both cases where the deterministic term include a constant, and a constant with a time trend).[1] The results of the KPSS tests are in line with the results of the ADF tests with one exception: this time the null of stationarity is rejected for both price series in levels in both cases where only a constant and both a constant and a time trend are included. Overall, both ADF and KPSS tests support unit roots in both real cotton and oil price series, in levels; both, however are stationary in their first differences and are I(1) variables.

Given this, there potentially exists a long-run relationship between real oil and cotton prices. To investigate further this long-run relationship for possible cointegration analysis, we use two tests: the Johansen trace test (1995) that assumes an intercept in the deterministic term, and the Saikkonen and Lutkepohl (S&L) test (2000) that proceeds by estimating the deterministic term first, subtracting it from the observations and then applying the Johansen type test to the adjusted series. The results of the Johansen trace and S&L tests are presented in Table 2. Both S&L and Johansen tests cannot reject rank 0 based on different lag orders. This suggests that there is no cointegration and further indicates that there is no long-run relationship between real cotton and oil prices.

The effects of shocks to real cotton prices in the U.S. are then derived from a SVAR model specification, given the absence of any cointegrating relationship. The impulse responses together with bootstrap confidence interval (95% Efron percentile confidence interval in 1000 replications) are shown in Figure 1. The three panels in Figure 1 show the impulse responses of real cotton price to each of the three demand and supply shocks that affect the crude oil market. Figure 1 shows that the responses of cotton price may differ depending on the underlying cause of the oil price increase. Unanticipated disruptions in crude oil production and increases in the

[1] However, when the deterministic terms include both constant and a time trend in the cotton price series, the null hypothesis of nonstationarity is rejected. To verify the results, KPSS tests were performed under different specifications of the deterministic terms.

precautionary demand for oil (oil-specific) do not have a significant effect on real cotton prices in the U.S. In contrast, unexpected increases in global demand for industrial commodities driven by higher global real economic activity cause a short-lived increase in U.S. cotton prices that lasts for only a month. Notice that in the middle panel of Figure 1, transmissions of shocks from increased economic activity in subsequent periods are not statistically significant based on the confidence intervals. The results indicate that unpredicted global oil supply disruptions such as unanticipated production cutbacks by OPEC plays very little or no role altogether in the sustained variability in the cotton market; they also suggest that recent fluctuations in cotton prices were driven by unusually high economic growth in OECD countries as well as additional demand from emerging countries such as China, Brazil, India, and Russia.

The forecast error variance decomposition in Table 3 quantifies how important the three innovations have been, on average, for U.S. cotton prices. It is based on a Choleski decomposition of the covariance matrix. In the short-run, the effect of these three shocks is small. On impact, only 1 percent of the variation in U.S. real cotton price is associated with shocks that drive the global crude oil market. This proportion modestly increases in the next two months and persists in the same proportion in the subsequent months. In the long run, 3 percent of the variability in the real cotton price is accounted for by an unexpected increase in the global demand for industrial commodities that drive the global crude oil market while a mere 1 percent of the variability in cotton prices can be attributed to precautionary oil demand shocks; none is accounted for by oil supply shocks. Overall, shocks in global oil demand due to improved economic activity are an important fundamental for the cotton market while oil supply shocks and precautionary demand shocks for crude oil do not provide much explanatory power for cotton price variation.

4. Conclusions

In this paper, the effects of oil price shocks on cotton prices have been examined. Time series properties of crude oil and cotton prices were examined and found to be first-difference stationary and no cointegration. Using Kilian and Park's first-differences SVAR model, it was found that the monthly changes in cotton prices were significantly affected by unexpected increases in the global oil demand driven by increased global real economic activity (and that the effect is a short-lived increase in cotton prices for a month). Shocks to global oil demand emanating from increased global activity can explain 3% of the long-run variation in U.S. real cotton prices. This particular result provides evidence on the asymmetry of the response of U.S. cotton prices to oil price shocks: whether these shocks are generated from the demand- or supply-side – an issue that has not been addressed in the current cotton-oil price literature. This information is useful for simulation and further analysis of various welfare studies and income stabilization policies for cotton farmers. These studies, in turn, enable quantification of the welfare effects of different policies and, consequently, aid in the planning, design, and implementation of various government programs (i.e. agricultural price stabilization schemes and income stabilization programs).

References

Baffes, J. 2007. "Oil Spills on Other Commodities." Policy Research Working Paper 4333, World Bank.

Baffes, J. and G. Gohou (2003). "The Comovement Between Cotton and Polyester Prices," World Bank Working Paper, WPS3534, available at http://www-wds.worldbank.org/servlet/WDSContentServer/WDSP/IB/2005/03/09/000012009_20050309101052/Rendered/PDF/wps3534.pdf.

Baker, A., and S. Zahniser (2006). "Ethanol Reshapes the Corn Market," Amber Waves, April, 2006. Available at http://www.agclassroom.org/teen/ars_pdf/social/amber/ethanol.pdf.

Breitung, J., Bruggemann, R., & Lutkepohl, H. (2004). Structural Autoregressive Modeling and Impulse Responses, in H. Lutkepohl & M. Kratzig (eds.), *Applied Time Series Econometrics,* Cambridge University Press, pp. 159-196.

Campiche, J., H. Bryant, J. Richardson, and J. Outlaw (2007). ''Examining the Evolving Correspondence between Petroleum Prices and Agricultural Commodity Prices.'' Paper Presented at the American Agricultural Economics Association Annual Meeting, Portland, OR, July 29–August 1, 2007.

Davidson, R. & MacKinnon, J. (1993). *Estimation and Inference in Econometrics,* Oxford University Press, London.

Fadiga M. and S. Misra. (2007). "Common Trends, Common Cycles, and Price Relationships in the International Fiber Market." *Journal of Agricultural and Resource Economics* 23(1): 154-168.

Harri, A., Nalley, L, and D. Hudson (2009). "The Relationship Between Oil, Exchange Rates, and Commodity Prices," *Journal of Agricultural and Applied Economics,* 41(2009):501–510.

Johansen, S. (1995). *Likelihood-based Inference in Cointegrated Vector Autoregressive Models,* Oxford University Press, Oxford.

Kilian, L. (2008). "Exogenous Oil Supply Shocks: How Big Are They and How Much Do They Matter for the US Economy?" *Review of Economics and Statistics,* 90: 216-240.

Kilian, L. (2009)**. "**Not All Oil Price Shocks Are Alike: Disentangling Demand and Supply Shocks in the Crude Oil Market," *American Economic Review*, 99(3), June 2009, 1053-1069.

Kilian, L. and C. Park (2009). "The Impact of Oil Price Shocks on the U.S. Stock Market," *International Economic Review,* 50 (4): 1267-87.

Kwiatkowski, D., Phillips, P.C.B., Schmidt, P. & Shin, Y. (1992). "Testing the Null of Stationarity Against the Alternative of a Unit Root: How Sure Are We That the Economic Time Series Have a Unit Root?" *Journal of Econometrics*, 54: 159-178.

Laws, F. (2009). "Lower Oil Prices Good and Bad for Cotton," available at http://southwestfarmpress.com/cotton/oil-prices-0213/.

Pan, S., S. Mohanty and M. Fadiga (2007). "Price Asymmetry in the US Fiber Markets," *Applied Economic Letters*, 14: 545-48.

Rapsomanikis, G. and D. Hallam (2006). "Threshold Cointegration in the Sugar-Ethanol-Oil Price System in Brazil: Evidence from Nonlinear Vector Error Correction Models," FAO Commodity and Trade Policy Research Working Paper No. 22, available at ftp://ftp.fao.org/docrep/fao/009/ah471e/ah471e00.pdf.

Saikkonen, P. & Lutkepohl, H. (2000). "Testing for the Cointegrating Rank of a VAR Process With an Intercept," *Econometric Theory*, 16: 373-406.

Yu, Tun-Hsiang, D.A. Bessler, and S. Fuller (2006). "Cointegration and Causality Analysis of World Vegetable Oil and Crude Oil Prices.'' Paper presented at the American Agricultural Economics Association Annual Meeting, Long Beach, CA, July 23–26, 2006.

Zhang, Q., and M. Reed (2008). ''Examining the Impact of the World Crude Oil Price on China's Agricultural Commodity Prices: The Case of Corn, Soybean, and Pork.'' Paper presented at the Southern Agricultural Economics Association Annual Meeting, Dallas, TX, February 2–5, 2008.

Table 1. Unit Root Tests on Real Cotton *(r_cotton)* and Oil *(r_oil)* Prices *(in logarithms)*: Augmented Dickey-Fuller (ADF) & Kwiatkowski, Philipps, Schmidt & Shin (KPSS)

Variable	Test	Deterministic terms	Lags	Test value	5% critical value	10% critical value
r_cotton_log	ADF	c	0	-1.36	-2.86	-2.57
			1	-1.54		
		c, t	1	-4.22*	-3.41	-3.13
			3	-4.30*		
	KPSS	c	1	17.03	0.46	0.35
			3	8.60		
		c, t	1	0.39	0.15	0.12
			3	0.21		
Δ r_cotton_log	ADF	c	0	-17.84*	-2.86	-2.57
			4	-9.64*		
		c, t	0	-17.82*	-3.41	-3.13
			4	-9.63*		
	KPSS	c	4	0.04**	0.46	0.35
		c, t	4	0.04**	0.15	0.12
r_oil_log	ADF	c	1	-2.52	-2.86	-2.57
			6	-1.70		
		c, t	1	-2.45	-3.41	-3.13
			6	-1.52		
	KPSS	c	1	5.02	0.46	0.35
			6	1.50		
		c, t	1	3.33	0.15	0.12
			6	1.00		
Δ r_oil_log	ADF	c	0	-12.21*	-2.86	-2.57
			1	-11.50*		
			5	-9.57*		
		c, t	0	-12.21*	-3.41	-3.13
			1	-11.51*		
			5	-9.60*		
	KPSS	c	1	0.13**	0.46	0.35
			5	0.10**		
		c, t	1	0.05**	0.15	0.12
			5	0.04**		

*reject nonstationarity at the 5% and 10% levels of significance
**fail to reject stationarity at the 5% and 10% levels of significance

Table 2. Test of Cointegration Between Real Cotton and Oil Prices: Saikkonen & Lutkepohl (S&L), and Johansen

Test	Deterministic terms	No. of lagged differences	Null hypothesis	Test value	90% critical value	95% critical value
S&L	c	2	r=0	5.26	10.47	12.26
			r=1	1.23	2.98	4.13
		3	r=0	4.45	10.47	12.26
			r=1	1.54	2.98	4.13
	c, t	2	r=0	9.68	13.88	15.76
			r=1	2.61	5.47	6.79
		7	r=0	7.99	13.88	15.76
			r=1	1.37	5.47	6.79
Johansen	c	2	r=0	6.95	17.98	20.16
			r=1	2.91	7.6	9.14
		3	r=0	5.08	17.98	20.16
			r=1	1.62	7.6	9.14
	c, t	2	r=0	22.21	23.32	25.73
			r=1	3.37	10.68	12.45
		7	r=0	20.42	23.32	25.73
			r=1	2.52	10.68	12.45

Table 3. Percent Contribution of Demand and Supply Shocks in the Crude Oil Market to the Overall Variability of U.S. Cotton Prices

Horizon	**Oil Supply Shock**	**Aggregate Demand Shock**	**Oil-specific Demand Shock**	**Other Shocks**
1	0.00	0.01	0.00	0.99
2	0.00	0.02	0.01	0.97
3	0.00	0.03	0.01	0.96
4	0.00	0.03	0.01	0.96
∞	0.00	0.03	0.01	0.96

Figure 1. Forecast Error Impulse Responses of U.S. Real Cotton Price (x-axis: months, y-axis: U.S. real price of cotton)