INSIDE CHINA'S POLYESTER FIBER INDUSTRY: WHY THE CAPACITY OVERHANG?

Maria Mutuc
Darren Hudson
Don Ethridge
Department of Agricultural and Applied Economics
Texas Tech University
Lubbock, TX
M. Dean Ethridge
Fiber and Biopolymer Research Institute
Texas Tech University
Lubbock, TX

Abstract

From 2001-2008, China's polyester output expanded at an annual rate of 18.8% buoyed by its thriving textile and apparel sector. Over the same period, China's consumption for textile raw materials, specifically polyester fiber, increased at an annual rate of 10%. In 2008, China's polyester output and use accounted for over 50% of global production and consumption. The large capacity additions in China coincided with high crude oil prices. From 2001 until the third quarter of 2008, sustained increases in the price of crude oil and petrochemicals resulted in higher raw materials costs. Excess capacity led to fierce competition and tempered the rise in polyester prices, shrinking producers' profit margins (Walker, 2008). Notwithstanding lower profits and numerous plant closures, China's output of polyester fiber continued to grow, although at a slower pace, while China's counterpart producers have reduced their polyester output in recent years. The objective of this paper is to characterize the production structure of China's polyester fiber industry and in so doing explain the industry's resilience to rising petrochemical prices, excess capacities, and diminishing profits in recent years.

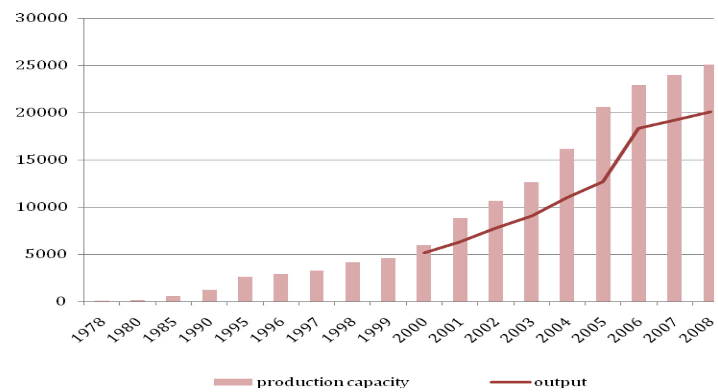
Introduction

Over the past three decades, much of the world's apparel production has shifted to Asian countries because of lower wage rates for the labor-intensive, cut-and-sew operations of textile and apparel manufacture. This shift in areas of production was facilitated by the Multi Fibre Agreement (MFA) where bilateral quotas were set between developed textile importing countries such as the U.S. and the E.U. and developing textile exporting countries such as China (Mutuc et al., 2009). China's trade advantage remained as the MFA was replaced by the Agreement on Textiles and Clothing (ATC) in 1995 which provided for the phased elimination of quotas (move to free trade) in the textiles and clothing sector within a *transitional* period of ten years, until 2005. Currently, a quarter of the world's exports of textiles come from China. To support the growth in its textile and apparel sector, China's demand for both natural and synthetic fibers as raw materials expanded. China's consumption of polyester fiber, in particular, increased from 12 million tons (mt) in 2004 to 19.1 mt in 2008. Broken down into polyester filament yarn (PFY) and polyester staple fiber (PSF), demand correspondingly increased from 7.2 mt and 4.8 mt in 2004 to 12.2 mt and 6.9 mt in 2008 (CCFEI, 2005-2008).

Output, capacities, location, and number of firms

In response to increased demand for polyester fiber, sizeable amounts of polyester were initially smuggled and dumped into China from excess production in South Korea and Taiwan from 1996-1999 (CCFEI, 2005). At the time, the polyester industry was dominated by inefficient, high-cost state-owned enterprises (SOEs). Shortly after 1999, anti-smuggling and anti-dumping efforts by the Chinese government stabilized the domestic polyester industry in China. Since then, the emergence of private companies has led to the successful development of a localized, domestic polyester industry so that by 2005 private enterprises accounted for 66.7% of national capacity, an increase of 24.3% over 2001 (China Chemical Reporter, 2006). These private enterprises used advanced technologies and equipment. But they also largely contributed to the rapid expansions that exceeded domestic and international use. Moreover, some remaining polyester units built in the 1990s (SOEs), characterized by high capital outlay, low quality, and high energy consumption operating mechanisms, that were expected to be thrown off the competition, instead expanded to be able to compete (CCFEI, 2005). Total capacity expanded from 5.95 mt in 2000 to 25.05 mt in 2008 with capacity utilization of about 80%, given domestic use at 19.10 mt (Figure 1). In other years, such as 2004 and 2005, capacity utilization was around 65%. Note that in general, exports account for only about 4-6% of China's polyester output but China accounts for over 50% of the world's production and consumption of polyester.

Figure 1. Production Capacity and Output, 1978-2008 (in 1000 tons)



Sources: China Chemical Reporter (26 December 2006), CCFEI (2002)

Polyester fiber processing in China is relatively concentrated geographically in the southeastern coastal provinces of Zhejiang and Jiangsu. Zhejiang province produces half of China's output of polyester fiber while Jiangsu province accounts for about a third. As of the first quarter of 2009, there were over 339 companies that manufacture PFY with a total capacity of 16.5 mt (includes chips). Of these, four manufacturers, with capacities above 800,000 tons, account for a fifth of total capacity; another four had capacities above 400,000 (but less than 800,000); 37 had capacities above 100,000 (but less than 400,000); the remaining majority had annual capacities below 100,000 tons. In the same period, there were approximately 110 manufacturers of PSF with combined capacity of about 6.9 mt. Of these processing plants, only two had capacities above 800,000 tons and made up 25% of total capacity; another two had capacities above 400,000 (and less than 800,000 tons); 16 plants had capacities above 100,000 (and less than 400,000 tons); all the rest had capacities below 100,000 tons.

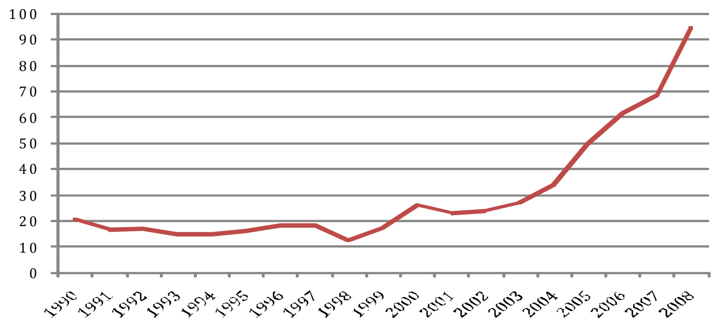
<u>Upstream chemical intermediates sector</u>

The capacity increases that have occurred since 2000 were built without reference to the ability to source polyester intermediates/feedstock such as purified terephthalic acid (PTA) and monoethylene glycol (MEG). PTA capacity in China has developed fast with a total capacity of 12.11 mt by the end of 2008. However, polyester capacity is much larger, with an average monthly demand for PTA of around 1.2 mt against the average monthly output of PTA of about 750,000 tons so that about 40% of total PTA consumed by the polyester industry was imported in 2008 (CCFEI, 2009).[1] Likewise, for MEG, China imports as much as 75% of the amount used in polyester production. As of June 2009, there are 16 manufacturers of MEG in China with total capacity of 1.9 mt per annum, 11 of which have capacities below 400,000, and 5 above 800,000 tons per annum.[2] Polyester is the main consumer of MEG in China, accounting for about 94% of total production, and has, in recent years, consumed about 5.6 mt of MEG every year. China uses approximately 27% and 35% of the world's PTA and MEG production, respectively.[3]

Although PTA and MEG can be sourced from other countries such as Japan, India, Taiwan, Singapore, South Korea, Indonesia, Kuwait, Iran, Saudi Arabia, Malaysia, and Thailand, increasing crude oil prices affected their affordability, being derivatives of petroleum. Not only did the large capacity additions occur without regard to feedstock availability, they coincided with the steady rise in crude oil prices from 2001 to 2007 (Figure 2). This further tightened the supply of feedstock in China's polyester industry.

<u>Electricity pricing in China</u>

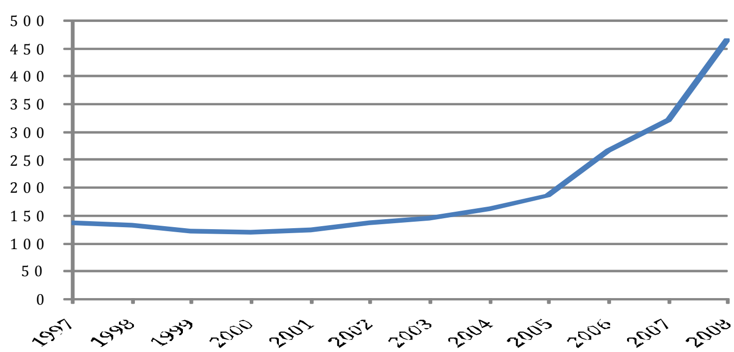
While rising crude oil prices resulted in higher prices of feedstock, increasing coal prices in the international market also impacted China's electricity sector (Figure 3). About 80% of China's electricity is generated by coal-fired



Source: BP

Figure 2. Crude Oil Prices, 1990-2008 (US$ per barrel)

plants. Although coal prices are determined by the market, electricity pricing remains largely government-controlled (Lam, 2004; Ma and He, 2008; Ngan, 2009, Xu and Chen, 2005). Wholesale and retail electricity prices are determined and capped by the National Development and Reform Commission (NDRC). Under a mechanism that links coal and electricity prices, if the price of coal rises 5% or more over a six-month period, electricity generating companies are allowed to pass onto consumers 70% of the corresponding cost increase (due to the fluctuation in coal prices), bearing the 30% of the cost increase (Ma and He, 2008). This mechanism was only implemented twice in the past three years (Wang et al., 2009). In fact, in some periods in 2006 and 2007 the government did not implement the mechanism and prevented the increase in electricity prices even though coal price rose by more than 5% in order to contain inflation and invigorate its manufacturing sector that has suffered from weakening overseas demand and rising labor costs (Yushi, Hong and Fuqiang, 2008; Wang et al., 2009). In short, electricity prices in China are highly subsidized and below the average total costs of generation and transmission (Lam, 2004). At the time when capacities were built into the polyester sector amidst rising feedstock prices, electricity price increases were muted that contributed to a lower cost of production of polyester than had the government allowed for a full pass-through of coal price increases.



Sources: Lin, Dong, & Li (2006), People's Daily Online (December, 2007)

Figure 3. Average Coal Power Prices in China, 1997-2008 (yuan per ton)

Methods

An industry's cost function summarizes all of the economically relevant aspects of its technology and can be used to investigate the same questions that are associated with a production function. In fact, given a cost function, one can "solve for" a technology that could have generated that cost function (Varian, 1992).[4] Numerous studies have used this one-to-one correspondence between the cost and production functions to characterize the structure of production and extent of market power across industries or countries (Ray, 1982; Capalbo, 1988; Garcia and Randall, 1994;

Tadesse, 2005; Yigezu, Foster and Lantz, 2006; Ali Akkemik, 2009). However, while such empirical studies have been done on the textile and chemical sectors (Chang and Robin, 2008; Agnolucci, 2009; Lee, 2008; Ma et al., 2009; Gupta and Taher, 1984), none have narrowly traced to the polyester fiber sector, much less to China.

In this paper we estimate a common flexible functional form called the transcendental logarithmic (translog) cost function to determine how domestic energy and labor pricing policies affect the demand for corresponding inputs in the polyester sector and how these impact on the industry's marginal cost and output. The translog's popularity arises from the fact that it is linear in its coefficients and contains still a fairly modest number of parameters (Stewart, 2005).

The translog cost function is specified as a function of time, input prices, output, and their interactions:

$$\ln(C^*) = \beta_O + \sum_{i=1}^{m}\beta_i \ln P_i^* + 0.5\sum_{i=1}^{m}\sum_{j=1}^{m}\beta_{ij}\ln P_i^* \ln P_j^* + \gamma_Q \ln Q + 0.5\gamma_{QQ}(\ln Q)^2$$
$$+\sum_{i}^{m}\gamma_{iQ}\ln P_i^* \ln Q + \delta_T \ln T + 0.5\delta_{TT}(\ln T)^2 + \sum_{i=1}^{m}\delta_{iT}\ln T \ln P_i^* + \delta_{QT}\ln T \ln Q + \varepsilon_O \quad (1)$$

where *ln* indicates the natural logarithm; C^* is total cost; P_i^* (P_j^*) denotes the price of an input factor *i (j)* ; *Q* is output level and *T* is time (assumed to capture technical change) (Capalbo, 1988; Ma et al., 2009; Yigezu, Foster and Lantz, 2006).

Factor demands (S_i) for a given output (conditional factor demands) can be obtained by differentiating (1) with respect to input prices to obtain a system of factor share equations:

$$S_i = \beta_i + \sum_{j=1}^{m}\beta_{ij}\ln P_j^* + \gamma_{iQ}\ln Q + \delta_{iT}\ln T + \varepsilon_i \quad (2)$$

with *i,j = C, E, L* (for chemicals, electricity, and labor respectively).[5] Note that in (2), factor shares are allowed to vary with factor prices, output and over time.

To ensure that the cost shares sum to 1, (1) was estimated by normalizing the cost and price variables using the price of labor as numeraire. Hence, we have C^* and P_i^* (P_j^*). Consequently, the share equation for labor was dropped. Symmetry restrictions, $\beta_{ij} = \beta_{ji}$ for all $i \neq j$, were imposed to enable us to estimate all the parameters. The translog cost function (1) and factor share equations (2) for both chemicals and electricity were estimated simultaneously as a system using seemingly unrelated regression (SUR).[6] Parameters that correspond to the dropped labor share equation were derived knowing certain regularity conditions that must hold to ensure that whenever factor prices are multiplied by some constant, total cost can be factored by the same multiple (linear homogeneity in factor prices):

$$\sum_{i=1}^{m}\beta_i = 1,\ \sum_{j=1}^{m}\beta_{ij} = 0,\ \sum_{i=1}^{m}\gamma_{iQ} = 0,\ \sum_{i=1}^{m}\delta_{iT} = 0, \qquad i,j = 1,..,m \quad (3)$$

<u>Elasticities of Substitution</u>

To determine the nature and extent of substitutability between factors, we use standard results from the one-to-one correspondence between production and cost functions; Allen partial elasticities of substitutions between input *i* and *j* were derived as:

$$\sigma_{ij}^A = \frac{\beta_{ij} + (S_i S_j)}{S_i S_j} \quad \forall i \neq j \qquad \text{and} \qquad \sigma_{ii}^A = \frac{\beta_{ii} + (S_i^2 - S_i)}{S_i^2} \quad (4)$$

A positive σ_{ij}^{A} between inputs i and j indicates that they are substitutes for each other in production, while a negative σ_{ij}^{A} implies that factors i and j are complements (must be used together). Because Allen partials may vary with the cost shares, the related own- and cross-price elasticities of demand for factors of production were derived as:

$$\varepsilon_{ij} = \sigma_{ij}^{A} S_{j} \quad \forall i \neq j \;\text{ for } i,j = C,E,L \tag{5}$$

so that while $\sigma_{ij}^{A} = \sigma_{ji}^{A}$, in general, $\varepsilon_{ij} \neq \varepsilon_{ji}$. In contrast to symmetric Allen partials, Blackorby and Russell (1989) derive the asymmetric measure of ease of factor substitution, the Morishima elasticity of substitution of input i by input j, and the opposite substitution of input j by input i as:

$$\sigma_{ij}^{M} = \varepsilon_{ji} - \varepsilon_{ii} \quad \text{and} \quad \sigma_{ji}^{M} = \varepsilon_{ij} - \varepsilon_{jj} \tag{6}$$

The asymmetry can be explained as follows. Equation 6 describes the percent change in the input quantity ratio, say x_i/x_j, with respect to a percent change in the corresponding price ratio, p_i/p_j. A change in p_i, holding p_j constant, has two effects on the quantity ratio: the first term, ε_{ji}, shows the effect on x_j, and the second term, ε_{ii}, shows the effect on x_i. In contrast, a change in p_j, holding p_i constant, has two different effects on the input quantity ratio which are given as $\sigma_{ji}^{M} = \varepsilon_{ij} - \varepsilon_{jj}$. There is no *a priori* reason that these effects should be the same (Stiroh, 1999).[7]

Economies of Scale

The estimated parameters can also be used to compute partial and overall scale economies (SE) at each data point that measure the relative change in output when costs change (due to more input use for a given set of input prices). There are three possible cases: (a) increasing returns to scale, (b) decreasing returns to scale, and (c) constant returns to scale. Increasing (decreasing) returns to scale is observed if costs increase less (more) than proportionately than output such that if the firm decides to produce twice as much output, it can do so at less (more) than twice the cost, as long as factor prices remain the same. Constant returns to scale is observed if costs increase proportionately as output so that doubling output entails twice the cost. From these definitions, it is easy to see that SE is the reciprocal of the cost elasticity with respect to output (η_{CQ}):

$$SE = \frac{1}{\eta_{CQ}} \tag{7}$$

where

$$\eta_{CQ} = \frac{d\ln C^{*}}{d\ln Q} = \gamma_{Q} + \gamma_{QQ}\ln Q + \delta_{TQ}\ln T + \sum_{i}\gamma_{iQ}\ln(P_{i}^{*}). \tag{8}$$

If SE >1, total costs increase by a lower proportion than the output and indicates increasing returns to scale (average cost of production will tend to fall as output increases); if SE <1, total costs increase by a greater proportion than output and is characteristic of decreasing returns to scale (average cost of production will rise as output increases) while SE =1 implies constant returns to scale (average cost remains the same even at higher output levels).

Rate of Technical Change

From the cost function in (1), the rate of technical change (RTC) is measured by:

$$TC = -\frac{\partial\ln C^{*}}{\partial\ln T} = -(\delta_{T} + \delta_{TT}\ln(T) + \delta_{TQ}\ln(Q) + \sum_{i}\delta_{iT}\ln(P_{i}^{*})) \tag{9}$$

TC gives the reduction in total costs due to technical progress given that output, input prices, and time remain constant. This is a measure of efficiency in production and represents the equivalent decline in costs of all inputs by applying better techniques.[8] Following Tadesse (2005), and Yigezu, Foster and Lantz (2006), equation (9) can be decomposed into three components or sources of change. First, $-(\delta_T + \delta_{TT} \ln T)$ represent the rate of reduction in total costs holding constant the efficient scale of production and factor cost shares; this often referred to as "pure" technical change, meaning the effects of size are removed. Second, ($-\delta_{TQ} \ln Q$) corresponds to scale-augmenting technical change which is the rate of reduction in total costs due to technical change that accompanies the change in output. In this measure, the effects of size are considered. Finally, $-\left(\sum_i \delta_{Ti} \ln(P_i^*)\right)$ embodies the overall input-bias of technical change. It captures input-mix changes that occur independently of relative input prices *over* time.[9]

Marginal Cost Function[10]

Given the cost function in (1), the marginal cost (MC) function can be expressed as (Garcia and Randall, 1994)[11]:

$$\frac{\partial C}{\partial Q} = AC * \left(\gamma_Q + \gamma_{QQ} \ln(Q) + \delta_{TQ} \ln(T) + \sum_i \gamma_{Qi} \ln(P_i^*) \right) \tag{10}$$

where AC is average cost and is a function of quantity and input prices. From (10), resulting changes in costs at the margin can also be computed. Specifically, we can compute for the change in MC if there is a change in the relative price of inputs, for a given output. It is derived as:

$$\xi_{MC}^{P_i} = \left(\frac{\partial MC}{\partial P_i} \right) \left(\frac{P_i}{MC} \right) = \frac{MC * S_i + AC * \gamma_{Qi}}{MC} \tag{11}$$

$\xi_{MC}^{P_i}$ is the elasticity of the MC with respect to the price of input *i*.

Considering that (a) the MC function is the supply function in the region where producers choose to operate, and that (b) the cost function in (1) does not include all variable cash inputs, parameter estimates are short-run.[12] Given this, we can use the MC as the supply and differentiate it with input and output prices to get short-run price elasticity estimates of the supply curve (Garcia and Randall, 1994):

$$\xi_Q^{P_i} = \left(\frac{\partial Q}{\partial P_i} \right) \left(\frac{P_i}{Q} \right) = \frac{-AC(MC * S_i + AC * \gamma_{Qi})}{MC^2 - AC * MC + AC^2 * \gamma_{QQ}} \tag{12}$$

where $\xi_Q^{P_i}$ is the elasticity of output with respect to the price of input *i*. The expression

$$\xi_Q^{P_Q} = \left(\frac{\partial Q}{\partial P_Q} \right) \left(\frac{P_Q}{Q} \right) = \frac{MC * AC}{MC^2 - MC * AC + AC^2 * \gamma_{QQ}} \tag{13}$$

shows how output responds to changes in the output price (price elasticity of output supply ($\xi_Q^{P_Q}$)).

Data

Monthly data on prices and quantities of inputs used in production, and input cost shares for the period 2004 to 2008 were used. Input prices include hourly wage rates, prices of chemical intermediates per ton (composite of PTA and MEG), and electricity rates per KwH. Input quantities include number of employees in the polyester sector, amount of electricity consumed by the polyester sector, and the amount of PTA and MEG used as chemical intermediates. Estimates of hourly compensation costs for manufacturing urban units and town and village enterprises (TVEs) by Banister (2005) and Lett and Banister (2006, 2009) were used for 2003-2006. The number of employees in the polyester sector was derived using monthly survey data on the terylene fiber industry (subsector 2822 of synthetic fibers sector 282) from All China Data Center.[13] The amount of PTA used in the manufacture of polyester fiber was computed knowing that 75% of net apparent demand (output + imports – exports) for PTA is used in polyester fiber production.[14] For 2006 onwards, data on net apparent demand was available from Chemical Fiber Economic

Information Network (CCFEI). To estimate net apparent demand for 2004-2005, the ratio of PTA demand to polyester output (3-month moving average for January-March of 2006) was used. The same procedure was applied to compute for the amount of MEG used in polyester fiber manufacturing, only this time 94% of net apparent demand was allocated to polyester fiber sector.[15] Total polyester fiber output (in 1,000 tons) includes both polyester filament yarn (PFY) and polyester staple fiber (PSF) output sourced from CCFEI.

The weighted average of end-of-month PTA and MEG cash/factory price in US$/ton was used for prices from Emerging Textiles. Polyester filament prices for partially-oriented yarn (150D/96F)/fully-drawn yarn (200D/96F)/drawn texture yarn (300D/96F) average price in $US/kilogram in China's Zhejiang market was used as indicator for output price. PSF prices were also available. Annual figures for electricity consumed by the chemical industry from China's National Statistical Yearbook were adjusted to a monthly basis using monthly output data for the chemical sector. The share of polyester fiber in the chemical sector's output was used to determine the amount of electricity consumed by the polyester fiber sector (in KwH per month). Electricity prices were derived using published information from Chinese news agencies.[16]

Results and Discussion

Parameter estimates are shown in Table 1. All estimated parameters are statistically significant at the $\alpha = 0.05$ level or less except for δ_{TC} (p-value = 0.195). Two assumptions on the nature of the dual production function were tested using likelihood ratio (LR) tests: (a) homotheticity, and (b) constant returns to scale.[17] Table 1 also contains the results of these tests. The corresponding LR statistics of 9.18 and 70.74 for both tests are greater than the corresponding critical values of 5.99 and 9.48 that allow us to reject the assumptions of a homothetic technology and constant returns to scale. Hence, a change in the level of polyester fiber produced alters the relative use of chemical intermediates, electricity, and labor (that is, over time, as output changes, the relative proportions of chemicals, electricity, and labor change).

Also, the rejection of the assumption of constant returns to scale is corroborated by the overall scale economies measure (SE) from equation (7) that shows the relative increase in output when costs change with higher input use. Using equation (7) yields an SE value of 0.801 (computed at mean values) which implies that output increases less than proportionately, by 0.801%, following a one percent increase in the cost of production. This further implies that the per-unit cost of production (average cost) increases with output so that decreasing returns to scale is observed. If the polyester industry were to double output, it will entail more than twice the cost. Figure 4 shows

Table 1. Parameter Estimates and Measures of Goodness-of-Fit

Parameter	Estimates[a]	Std Error	P>z	[95% Confidence Interval]	
β_C	-0.9795	0.2832	0.0010	-1.5347	-0.4244
β_E	1.4754	0.2629	0.0000	0.9601	1.9906
β_{CC}	0.1009	0.0111	0.0000	0.0792	0.1226
β_{CE}	-0.1528	0.0502	0.0020	-0.2511	-0.0544
β_{EE}	0.1475	0.0466	0.0020	0.0563	0.2388
γ_Q	3.0165	0.3178	0.0000	2.3935	3.6394
γ_{QQ}	-0.2180	0.0425	0.0000	-0.3012	-0.1348
γ_{QC}	0.0543	0.0112	0.0000	0.0323	0.0763
γ_{QE}	-0.0285	0.0103	0.0060	-0.0488	-0.0082
δ_{TQ}	0.2675	0.0776	0.0010	0.1155	0.4196
δ_T	-3.6588	1.0283	0.0000	-5.6742	-1.6433
δ_{TT}	-0.0580	0.0262	0.0270	-0.1093	-0.0067
δ_{TC}	0.0000	0.0000	0.1950	0.0000	0.0001
δ_{TE}	-0.0028	0.0006	0.0000	-0.0040	-0.0015
δ_{TL}	0.0027				
β_L	0.5042				
β_{CL}	0.0518				
β_{EL}	0.0052				
β_{LL}	-0.0571				
γ_{QL}	-0.0258				

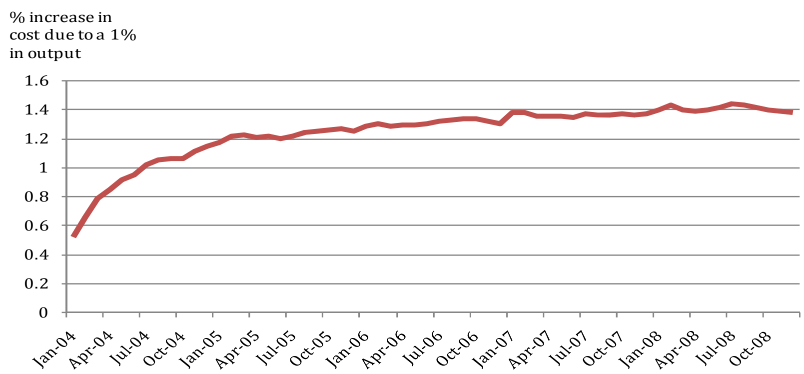
Equation	RMSE	R^2	χ^2	P-value
Cost	0.1101681	0.8337	2.83E+06	0.00000
Share of chemical intermediates	0.0137305	0.5411	156.72	0.00000
Share of electricity	0.0122548	0.5486	94.71	0.00000

[a] The last six parameters were derived using the adding up restrictions. Constant in the cost equation was dropped due to multicollinearity.

Homotheticity: $\gamma_{QQ}=\delta_{TQ}=0$, LR $\chi 2_{(2)} = 9.18$

Constant returns to scale: $\gamma_Q=0$, $\gamma_{QC}=0$, $\gamma_{QE}=0$, LR $\chi 2_{(4)}=70.74$

how costs respond to a percentage increase in output (elasticity of cost with respect to output) between 2004 and 2008. Note that the elasticities of cost with respect to output using equation (8) ranged from 0.52 for the first quarter of 2004 to 1.44 in recent months (at different output levels). After the first quarter of 2004, average cost of production started to increase. During the same period, capacity utilization declined from 72% in 2003 to 68% in 2004 and further down to 62% in 2005 - years where additional capacities rose faster in the sector. Capacity utilization later recovered in 2006 onwards (Figure 1).



Source: Author's computations.

Figure 4. Elasticity of Cost with Respect to Output, 2004-

Tables 2-4 present results on the extent that factors of production have responded to input price changes in China's polyester fiber production. Table 2 shows how the demand for a particular input changes in response to a change in its own price (own price elasticity) as well as a change in the price of other inputs (cross-price elasticity). From Table 2 we can say that chemical intermediates, electricity and labor are pair-wise substitutes (in response to price changes) given the positive cross-price elasticity estimates derived using equation (4). Producers' demand for chemicals and electricity are not highly responsive to changes in wage rate (correspondingly 0.0225 and 0.0215 in Table 2) whereas input demand for labor and electricity are highly sensitive to changes in the price of chemical intermediates (correspondingly 0.9043 and 0.7284). Input demands for chemicals and labor are affected almost similarly by higher electricity rates (correspondingly 0.1008 and 0.1196). Own-price elasticities are expected to be negative. In this case, however, with a positive own-price of elasticity for electricity, it appears that producers do not cut back on electricity use even if the price of electricity increases. This is partly explained by the fact that electricity increases have been modest in recent years than what would otherwise be if electricity rates were allowed to move with fuel price increases.

Allen partial elasticities of substitution (Table 3) indicate ease of *technical* substitutability. Chemicals and labor are easily substitutable (1.05), followed by electricity and labor (1.005); there is less substitutability between chemicals and electricity (0.8472). However, from the Morishima elasticity estimates in Table 4, these technical substitutions between inputs are *asymmetric* (the rate at which one factor can be substituted for another is not the same going the other direction). Substitution of labor by chemicals is relatively easier (3.666) relative to the substitution of chemicals by labor (0.9272). Substitution of chemicals by electricity (0.7513) is possible while electricity needs to be used with chemicals (complemented by chemicals (-0.2587)).

Table 2. Own- and Cross-Price Elasticities[c]

	Chemicals	Electricity	Labor
Chemicals	-0.0229	0.1008	0.0225
	(0.0022691)	(0.0018292)	(0.0007073)
Electricity	0.7284	0.3594	0.0215
	(0.0217211)	(0.0210937)	(0.0008098)
Labor	0.9043	0.1196	-3.6435
	(0.0760183)	(0.0070825)	(0.0828479)

[c] Significance level for all estimates is 1%.

Table 3. Allen Elasticities of Substitution[d]

	Chemicals	Electricity	Labor
Chemicals	-0.0267	0.8472	1.0518
	(0.002794)	(0.02388)	(0.0823565)
Electricity		3.0221	1.0052
		(0.2484791)	(0.0878970)
Labor			-170.1229
			(10.13347)

[d] Significance level for all estimates is 1%.

Table 4. Morishima Elasticities of Substitution [e]

	Chemicals	Electricity	Labor
Chemicals		0.7513	0.9272
		(0.023878)	(0.0748238)
Electricity	-0.2587		-0.2399
	(0.0228585)		(0.0219468)[f]
Labor	3.6660	3.6650	
	(0.0821797)	(0.0825641)	

e Significance level for all estimates is 1% unless otherwise stated.

f Statistically not significant.

In general, these results suggest three things. First, polyester production is chemical-intensive as evidenced by the low substitution elasticity of chemicals by both labor and electricity. Second, electricity cannot be replaced technically (substituted) by any factor (corroborated by the positive own-price elasticity of demand for electricity in Table 2). In fact, electricity is complemented by both. Third, in contrast to electricity, labor can be substituted by both chemicals and electricity.

Table 5 presents the sensitivity of marginal cost (MC) and output in response to input price increases. From Table 5 it is apparent that MC and output supply are most sensitive to changes in chemical prices and least responsive to changes in wage rates. In terms of marginal cost response, a 1% increase in MEG or PTA prices increases marginal cost by 0.9032% while a 1% increase in electricity and wage rates raises marginal cost by only 0.0961% and 0.0007%, respectively. This is consistent with the earlier result derived from looking at the cross-price elasticities - labor is easily substitutable in contrast to chemical intermediates. The output price elasticity of supply of 13.66 using equation 13 suggests that fiber producers are willing to increase supply more than proportionately in expectation of higher profits.

Table 5. Marginal Cost and Supply Elasticities

	Marginal cost elasticity with respect to	Supply elasticity with respect to
Price of chemical	0.9032	-12.3438
Electricity rate	0.0961	-1.3133
Wage rate	0.0007	-0.0097

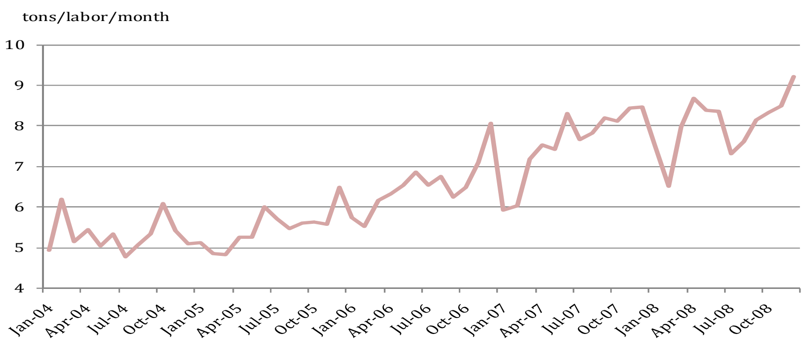
A breakdown of the rate of technical change into its components partly explains why the industry has experienced increasing average costs. Table 6 shows that the measure for scale-augmenting technical change is negative (-3.7623) which suggests that, on average, the technological change that accompanied the expansion in the

Table 6. Breakdown of Rate of Technical Change

Source of technical change	Estimate	Standard error
Pure technical change	3.841196	0.006780
Scale-augmenting technical change	-3.762311	0.008553
Input-biased technical change	-0.006311	0.000018

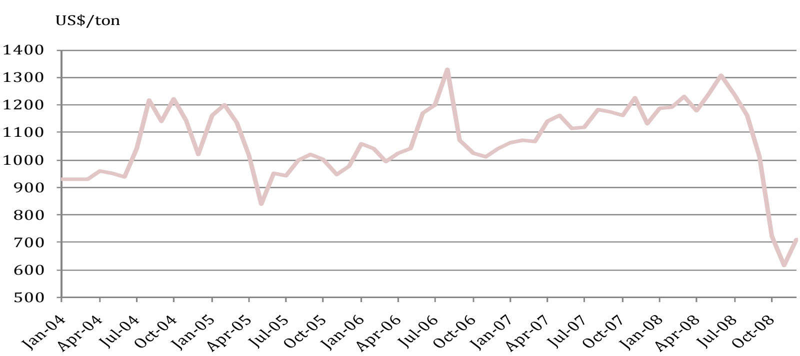
Note: All estimates are significant at the 1%

industry's output has resulted in higher costs. Note that this coefficient implies a negative reduction (an increase) in unit cost of production. On the other hand, the measure of pure technical change is positive and significant (3.8411) which implies that there was a positive reduction in total cost over the period 2004 to 2008, on average (holding constant *efficient* scale of production and input shares in total cost). Gains in labor productivity, measured in output per labor hired, partially explains this improvement in technical efficiency (Figure 5). Finally, based on the input-bias component of technical change measure (-0.0063), total costs increased as a result of changes in relative input prices (accompanying technological change) during 2004-2008. Figure 6 confirms that chemical prices have continuously risen starting July of 2005. Accounting for all the sources of technical change, Figure 7 shows that while a relatively large reduction in total costs occurred up until the end of the first quarter of 2005, this rate of reduction started to slow down in the following quarter; it now stands at only about 2%.



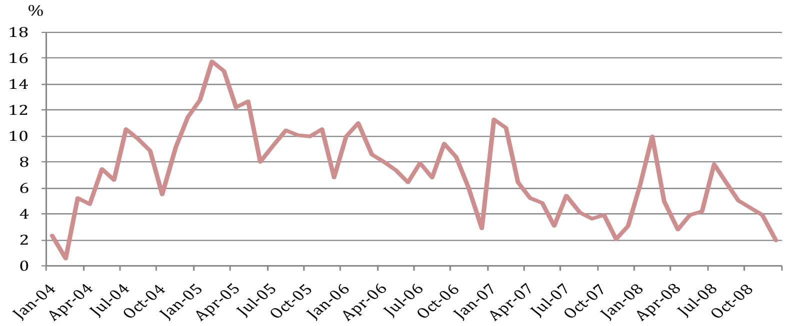
Sources: CCFEI, All China Data Center

Figure 5. Labor Productivity, 2004-2008 (monthly output per labor hired)



Sources: CCFEI, Emerging Textiles

Figure 6. Price of Chemical Intermediates, 2004-2008 (in US$/ton)



Source: Author's computations.

Figure 7. Rate of Reduction in Total Costs, 2004-2008

Policy Implications and Conclusions

The empirical results underscore characteristics of the production technology that underlies China's polyester fiber industry in three areas: (a) input use, (b) the response of output and costs to input and output price changes, and (c) the technology that accompanied output growth.

First, on input use, three things are worth noting. First, polyester production is chemical-intensive as evidenced by the low substitution elasticity of chemicals by both labor and electricity. Second, electricity cannot be replaced (technically substituted) by any factor (corroborated by the positive own-price elasticity of demand for electricity in Table 2) given the current technology in polyester manufacturing in China. In fact, electricity is complemented by both labor and chemicals. Third, in contrast to electricity, labor can be substituted by both chemicals and electricity. Given the foregoing, current policies that cap the increase in electricity rates have restrained the rise in the cost of polyester fiber production. Highly subsidized electricity prices in China that are lower than the average cost of generation and transmission of electricity has increased the incentives of both domestic and foreign enterprises to continue to invest in new polyester capacity. On the other hand, labor is found to be easily substitutable for this industry owing to the large supply of surplus urban and rural workers in China (Banister, 2007). The data also show that the amount of output per labor hired for the sector has increased over time, signifying higher labor productivity. This is consistent with other empirical work where the growth rate of labor productivity in the chemical fiber sector in China was found to increase by 16.6% for 2003-2006 (Kim and Kuijs, 2007). Current policies that help curb wage increases, concurrent with productivity improvements, has also limited the increase in the cost of production.

Second, on the response of marginal cost and output supply on input and output price changes, output supply is most sensitive to changes in chemical prices and least responsive to changes in wage rates. Also, policies aimed at higher polyester fiber prices have a bigger output effect than those that reduce chemical intermediates prices given an output elasticity of supply (-12.3438) that is greater than the chemical price elasticity of supply (0.9032).

Third, the technological change that accompanied the expansion in the industry's output has resulted in higher costs, which became apparent beginning second quarter of 2005. Hence, polyester fiber production in the past four years has experienced decreasing returns to scale that resulted in higher average costs. This could precipitate fragmentation or downsizing of existing firms to attain the minimum efficient scale at which average cost is the lowest given current technology unless the issue of self-sufficiency in feedstock supply is addressed that can lower raw materials costs. Up until recently, over 35 percent and 75 percent of total demand for PTA and MEG, respectively, are imported by China's polyester sector.

The story behind the transformation of China's polyester fiber industry is simple. Production capacity continuously expanded beginning 1999, following anti-dumping and anti-smuggling efforts by the government against polyester fiber coming from extra capacities in South Korea and Taiwan (CCFEI, 2005); this stabilized the domestic polyester market in China. While domestic firms continued to expand capacities (where only about 4% of output is exported), the upstream chemical intermediates remained highly import dependent. And because fiber production highly responds to output prices determined by the downstream textile industry (sales to production ratio of the polyester industry is at 98% in recent years, according to the CCFEI), supply bottlenecks in the upstream chemical sector occurred in recent years with a strong domestic textile sector that needed more polyester fiber (at least until Q3 of 2008). These bottlenecks raised PTA and MEG prices, and because they account for about 86% of the cost of production (and given that chemicals are not easily replaced by labor or electricity in polyester production), the average cost of polyester production has increased. This tightness in feedstock supply helps explain why excess capacities remain in China's polyester fiber sector. More recently, on the demand side, the downturn in the global economy has weakened the demand for fiber and consequently for chemical intermediates.

For as long as producers face distorted input prices because electricity rates do not reflect the actual cost of electricity generation, or as long as labor costs only partially account for labor productivity, the incentive to over-invest in polyester fiber production infrastructure and the overhang in capacity remain, given current demand for Chinese textiles.

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Endnotes

[1] Historically, China imports 60-65% of its domestic demand for PTA.
[2] No reliable information on the number of PTA firms is available since some PTA producers are integrated with PSF/PFY producers and are hence listed under PFY/PSF processing units.
[3] Assumes that China consumes 750,000 tons of PTA per month and converted on an annual basis. Capacity figures used as proxy for world production (as capacity utilization is in the range of 90-100%).

[4] Economists refer to this as the duality between the production and cost functions wherein any concept defined in terms of the properties of the production function has a "dual" definition in terms of the properties of the cost function and vice-versa (Varian, 1992).

[5] Shephard's Lemma tells us that the derived demand for a factor, which is in general a function of its own price and the price of other factors and is conditional on the level of output, may be obtained simply as the derivative of the cost function with respect to the price of that factor.
[6] A SUR model is a system of regression equations that do not share an identical set of regressors. In the joint estimation of the translog cost share equations (conditional factor demand equations) together with the cost function, not all parameters of the cost function appear in the factor demands so that SUR is appropriate.
[7] Using Equation (6) allows for the possibility that positive Allen partials (substitutes) yield negative Morishima elasticities (complements), and vice-versa, depending on the relative values of the first and second terms.
[8] In terms of the dual production function, this increase in efficiency is represented by a downward parallel shift of the isoquants in input space. An isoquant is simply a plot of alternative factor combinations that can be used to produce a particular level of output.
[9] Permits isoquants to be displaced in input space.
[10] Marginal cost is defined as the increase in total cost due to the production of an additional output.
[11] This follows from $\eta_{CQ} = \left(\frac{\partial C}{\partial Q}\right)\left(\frac{Q}{C}\right)$ so that $MC = \frac{\partial C}{\partial Q} = AC * \eta_{CQ}$.
[12]In economics, the short-run supply curve of a competitive firm is that portion of its short-run marginal cost curve that is upward sloping and lies above the average variable cost curve. The firm will not operate on those points on the marginal cost curve below the average cost curve since it could have greater profits by shutting down (Varian, 1990).
[13] Terylene is what the first polyester was called.
[14] *China PTA (Pure Terephthalic Acid) Market Report*, *2008-2009*. China Consulting, April 2008. Accessed July 3, 2009 http://www.researchandmarkets.com/reports/613709.
[15] China Chemical Reporter (6 October 2007).
[16] According to Thomson (2005), electricity prices from RMB 0.5155/KwH to RMB 0.5654/KwH between January 2003 and August 2004. Two more rounds of price increases occurred in May 2005 (increase of RMB 0.0252/KwH) and in August 2005 (RMB 0.06/KwH) for select provinces, including Zhejiang (China Daily, 2005)). In May 2006, another increase of RMB 0.0252/KwH occurred (Thomson, 2005). In July 2008, domestic electricity prices were once again raised by RMB 0.0252/KwH.
[17] Likelihood ratio tests (LR) determine whether there is a difference in the likelihoods between the model which contains the restrictions tested (H_0) and the unrestricted model without restrictions (H_1) based on the statistic $\lambda=-2[\ln\{L(H_0)-\ln\{L(H_1)\}]$, where $L(H_0)$ and $L(H_1)$ denote the values of the likelihood function under the null and the alternative, respectively.