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# An Empirical Study of Trade Competitiveness in the U.S. Technical Textile Industry

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## ABSTRACT

*In the last decade, technical textiles have played an increasingly important role in the US textile economy in terms of both size and impact. In addition to a well-established position in domestic market, the industry has realized that the long-term growth of US technical textile sector relies on its continuous expansion in the international markets. However, based on an extensive literature review, the published work on the US technical textile performance and competitiveness in international trade is very little.*

*This paper identified the impacts of major economic and political factors on the US technical textile export to its 15 major trading partners between 1996 and 2006 and analyzed the US trade performance with these nations over the time period. Ordinary-least-square (OLS) regression under a gravity model framework was employed to construct the analysis. The shifting patterns of US trade performances with these major trading partners were further revealed using the calculated relative difference index (RDI). Overall, the determinants identified from this analysis provide a better understanding of the changing patterns of US technical textile export and give researchers insights for further exploration. The empirical evidence derived from this study enable government officers and industrial practitioners to make effective decisions on trade policies, investments, and export marketing.*

*Keywords: technical textiles, international trade, gravity model, relative difference index*

## 1. INTRODUCTION

In the last twenty years, the US textile industry has been at the forefront of globalization and experienced a radical transition similar to those unfolding in many other US manufacturing sectors (Gereffi and Memedovic, 2003). Competitive pressures have steadily escalated as a result of continued international trade liberalization, including the phase-out of textile and apparel quotas under the World Trade Organization (WTO), the creation of the North American Free Trade Area (NAFTA), and the growing number of US bilateral preferential trade agreements (PTAs) and free trade agreements (FTAs) (Amponsah and Boadu, 2002). Against this backdrop, the industry as a whole has witnessed a sharp downturn since 1997 (Kilduff and Priestland, 2001). Within this overall picture, technical textiles have become a much more prominent component of the industry's product mix as apparel and home textile production have significantly contracted (Chang and Kilduff, 2002). This situation has been further reinforced by a wave of technological innovation over the last few years that has advanced process and product technologies, and diversified the numbers and applications of technical textile products (Author *etc.*, 2005). According to Textile Institute's Textile Terms and Definitions (1995), technical textiles refer to textile materials and products intended for end-uses other than non-protective clothing, household furnishing and floor covering, where the fabric or fibrous component is selected principally but not exclusively for its performance and properties as opposed to its aesthetic or decorative characteristics. Nowadays, technical textiles have been applied in a variety of end-use markets, including transportation, military, healthcare/medical, construction, and agriculture *etc.*

As competition continues to intensify across traditional apparel-related textile sectors, an increasing number of US manufacturers in these markets are seeking to switch over to technical products to survive and grow (Chang and Kilduff, 2002). Based on Fiber Organon's data, the US fiber consumption in technical end-uses was 1.88 billion kg in 2007, or 38% of a total fiber consumption of 4.96 billion kg. Table 1 details US mill fiber consumption by end-use destination in 1992, 1997, 2002 and 2007 respectively. The radical decline in apparel and home textile production since 1997 and the downward trend in carpet production in the last few years are evident while fiber consumption in technical type products has remained more resilient. Author *et al.* (2005) estimated that the value of technical textile shipments in the US was around $20 billion in 2002, accounting for some 33% of total value of shipments by the US textile industry. The total workforce in this sector of the industry rose slightly between 1997 and 2007, reaching some 200 thousand in the latter year (US Department of Labor, 2008). This contrasts sharply with the apparent decline of overall textile and apparel employment over this period.

**Table 1. US mill fiber consumption by end-use destination in selected years (unit: million kg)**

| | 1992 | 1997 | 2002 | 2007 |
|---|---|---|---|---|
| Apparel | 2,733 | 3,200 | 2,167 | 914 |
| Home textiles | 1,099 | 1,260 | 1,180 | 427 |
| Floor covering | 1,498 | 1,842 | 1,980 | 1,742 |
| Technical textiles* | 1,422 | 1,760 | 1,843 | 1,879 |
| Total | 6,752 | 8,062 | 7,170 | 4,962 |

Source: Fiber Organon various issues.
Note: * Fiber Organon uses the term 'Industrial Textiles' to classify this segment. For purposes of consistency the term 'Technical' has been substituted.

The North American market for technical textiles accounted for around one third of global consumption by weight in 1995 but its share of world consumption has been continuously falling due to the faster growth of markets in emerging economies (David Rigby Associate, 2002). Table 2 shows the estimates of technical textile consumption by geographic region up to 2010. It indicates that Asian consumption is not only higher than in the Americas and Europe but that it is also growing faster. In dollar term, by 2010, the global technical textile market is projected to reach some US$130 billion (Memon and Zaman, 2007).

**Table 2. Technical textiles and industrial nonwovens: forecasts of final consumption by region (unit: '000 metric tons)**

| | | | | Average Ann Growth % | |
|---|---|---|---|---|---|
| Region | 2000 | 2005 | 2010* | 00-05 | 05-10 |
| Americas | 5,031 | 5,777 | 6,821 | 2.8% | 3.4% |
| Europe | 4,162 | 4,773 | 5,577 | 2.8% | 3.2% |
| Asia | 6,963 | 8,504 | 10,645 | 4.1% | 4.6% |
| Other | 558 | 628 | 730 | 2.4% | 3.1% |
| Totals | 16,714 | 19,683 | 23,774 | 3.3% | 3.8% |

Source: David Rigby Associate, 2002.
Note: *: 2010 data are projected.

In contrast to an established strong position focused on domestic market needs, the expansion of US technical textiles in the international markets are relatively modest although Smith (2001) indicated that the long-term future of the industry depends on the development of international markets. The rapid growth of international markets creates broader opportunities for the US technical textile industry. However, compared to the substantial number of studies developed on domestic market needs, the research of US technical textiles' competitiveness in international trade is still sparse in the professional or academic literature. This is in part because much of the prior work focuses on aggregate trends in textiles and apparel. It is also because technical textile sector was a relatively small fraction of industry activity in the past and this has perhaps led to an unconscious neglect.

In order to fill this gap in the literature, this study empirically investigated the effects of major economic and political factors on the US technical textile exports to its 15 major trade partners between 1996 and 2006. Ordinary-least-square (OLS) regression under the gravity model framework was utilized to construct the analysis. The changes of US trade performance in technical textiles with these major trading partners were further revealed by the calculated relative difference indices (RDIs).



The remainder of this article is structured as follows. The next section provides an extensive review of the literature related to the development of the gravity model and its applications in analyzing international trade. In the methodology section, a commodity specific gravity equation is proposed for US technical textile exports. The independent and dependent variables and the analytical method - OLS linear regression are described. In addition, the RDI of bilateral trade is introduced for assessing the changing trade performance. Thereafter, the analytical results and discussion follow. The conclusions section presents the findings of this study and the implications for academic researchers, industrial practitioners, and government officials. Finally, the extensions for future research are offered.

## 2. LITERATURE REVIEW

Tinbergen (1962) and Pöyhönen (1963) were the pioneers who developed gravity models in their respective studies of international trade flows. Gravity models are mathematical models based on an analogy with Newton's gravitational law which states that any two objects exert a gravitational force of attraction on each other and the magnitude of the force is proportional to the product of the gravitational masses of the objects and inversely proportional to the square of the distance between them. In the analogy, trade flows between two nations are based on the economic analog of the mutual gravitational force between the two nations, with their national incomes (typically GDP) reflecting mass. Therefore, countries with a larger economy tend to trade more in absolute terms than those with smaller economies, while increasing geographic distance between two nations tends to depress bilateral trade - as communication costs rise. The original gravity model developed in the international trade flow analysis is listed as follows.

$$T_{ij} = A \times \left(\frac{Y_i \times Y_j}{D_{ij}}\right) \quad (1)$$

where
$T_{ij}$ is trade flow from country $i$ to country $j$, $Y_i$ and $Y_j$ are their respective national incomes (GDP), $D_{ij}$ is the geographic distance between them, and $A$ is a constant.

In the last four decades, the gravity model has been widely praised as one of the most effective international trade analysis tools (Anderson, 1979; Bayoumi and Eichengreen, 1995; Linnemann, 1966). More recently, Anderson and van Wincoop (2003) indicated that the gravity model is one of the most empirically successful trade analytical tools in economics.

Besides its success in the empirical application, the gravity model has also been validated as a method grounded in solid theoretical foundation. There are a number of studies that have attempted to provide a theoretical foundation for the gravity model and validate its application in international trade studies. These have typically sought to derive the gravity model from well-established theoretical models in international trade, notably the Ricardian model, the Heckscher-Ohlin (H-O) model, and the intra-industry trade model. Table 3 summarizes some previous studies on the theoretical foundation of gravity model.

**Table 3. A summary of prior research on the theoretical foundation of gravity model**

| Authors | Contributions |
|---|---|
| Linnemann (1966) | He asserted that the gravity model is a reduced form of a four-equation partial equilibrium trade model of export supply and import demand. Linneman's version of the gravity model was grounded in that of a Walrasian general equilibrium model which is a branch of theoretical microeconomics and seeks to explain production, consumption and prices in an economy. He concluded that differentiated production of goods between countries spurred bilateral trade while homogeneous production inhibited bilateral trade. |
| Anderson (1979) | He proved that the gravity equation can be derived from the properties of the expenditure system with the assumption of identical homothetic preferences across regions. He suggested that "products are differentiated by place of origin. The gravity model constraints the pure expenditure system by specifying that the share of national expenditure accounted for by spending on tradables is a stable unidentified reduced-form function of income and population" (p.106). |
| Bergstrand (1989) | Based on the framework of a general equilibrium trade model, Bergstrand demonstrated how the gravity model fitted into the H-O model and the intra-industry trade model. He provided an explicit theoretical foundation for exporter and importer incomes and per capita incomes consistent with established trade theories. |
| Deardorff (1995) | His work established the link between the gravity model and the H-O model by deriving the gravity model from two separate cases of the H-O model. Deardorff indicated that some of the equilibriums in the H-O model provided |

| | |
|---|---|
| | evidence that was consistent with that of the gravity equation. |
| Evenett and Keller (2002) | They analyzed the accuracy of perfect specialization versions of the H-O model and the intra-industry trade model and concluded that both supported the gravity model. They emphasized that these two important trade theories can account for the empirical success of the gravity model. |
| Anderson and van Wincoop (2003) | The study derived an operational gravity model with an elegantly simple form based on the CES expenditure system. |

All of these prior studies have established a solid theoretical foundation for the gravity model and refuted most of its criticisms. In fact, Frankel (1998) has pointed out that "the gravity equation passed from a poverty of theoretical foundation to an overwhelming richness (p. 2)."

Since its appearance over 40 years ago, there have been numerous applications of the gravity model in analyzing international trade flows (e.g., Asilis and Rivera-Batiz, 1994; Chen, 2008; Dascal et al., 2002; Porojan, 2000; Wall, 1999). Many have made contributions to its development and refinement. Nowadays, the primary form of a gravity model has been established as log-linear form with the core variables of income, population, and distance deemed requisite. Additional variables may be included according to the researcher's focus of interest. Sanso *et al.* (1993) empirically demonstrated that the log-linear form was efficient and concluded that the log-linear specification is a fair and ready approximation of the optimal form.

In the last decade, with the increasing number of FTAs and PTAs being implemented, many scholars have introduced these as additional explanatory variables into their gravity equations. For example, Soloaga and Winters (1999) examined the effects of FTA's and PTA's on trade creation and trade diversion. Krueger (2000) analyzed tariff differentials for US imports from Mexico and East Asia and found little evidence that trade patterns had been significantly altered by FTAs or PTAs. However, the results did suggest that NAFTA countries imported less than predicted from non-member countries. De Blasi *et al*. (2007) examined the magnitude of the trade flows for high quality wine from Italy to its main importing countries using an enhanced gravity model. The study provides a quantitative evaluation of the export gains that could result from the enlargement of the EU and from an increasing liberalization in international trade.

Besides its extensive application in the analysis of trade flows, the gravity model has also been increasingly used in other areas, such as migration flow analysis (Karemera and Oguledo, 2000), foreign direct investment (FDI) analysis (Brenton *et al.*, 1999; Frankel and Cavallo, 2004), and market area analysis (Baker, 2000).

## 3. METHODOLOGY

### 3.1 Variables and proposed gravity equation

Given the importance of international market for the sustainable growth of the US technical textile industry, it is imperative to develop a well-structured study to quantitatively identify the determinants of US technical textile exports and their individual effects in terms of significance and direction. The investigated factors in this study are not exhaustive but extensive and representative.

The relationships between the US technical textile export flows on the one hand and the various investigated variables on the other hand were tested by OLS regression method under the gravity model framework. The main advantage of OLS analysis is that it can be utilized to estimate the independent effect of each factor while holding constant the effects of the other variables (Hufbauer *et al.*, 1997). Data for the US and its 15 major technical textile trading partners between 1996 and 2006 were collected. Koo and Karemera (1991) indicated that the use of cross-year panel data is more suitable than single year data in bilateral trade analyses. They pointed out that a particular year may not provide accurate information to evaluate the trade flow pattern of a commodity.

Using the logarithm technique, the gravity equation can be converted to a linear form for econometric analysis. In the developed gravity equation, the log of US technical textile export values in millions of US dollars to its 15 major trading partners was the dependent variable. All investigated factors were the independent variables, including GDP, GDP per capita, population, population growth rate, geographic distance, country adjacency, infrastructure level, language commonality, tariff, and common membership under a FTA, PTA, or trade organization.

The GDP of the exporting nation measures productive capacity, while that of the importing country measures absorptive capacity (Pöyhönen, 1963; Tinbergen, 1962). A larger GDP in importing countries creates a larger demand for imports and similarly a greater GDP in exporting countries represents a greater production potential and could result in a larger supply for exports (depending on the ratio of its production for exports to total production). Differences in GDP per capita are presented as indicators of capital or labor-intensive trade and to express the level of economic development (Koo and Karemera, 1991). In this study, GDP and per capita GDP were expressed in purchasing power parity (PPP). This is consistent with the conclusions of Paas's (2003) study, which indicated that GDP and per capita GDP expressed in terms of PPP are more suitable in the gravity model analysis.



Population is used as measure of country size (Linnemann, 1996). Population growth rate is used to reflect demand in the importing country. It is expected that the higher the population growth rate, the greater the import value. (Brada and Mendex, 1983)

Geographic distance is a proxy for transportation costs (Frankel and Rose, 2002). A number of previous studies showed that trade flows decreased with increased distance between bilateral traders (e.g., Aitken, 1973; Bergstand, 1985; Linnemann, 1996). However, in some recent work, the findings suggested that distance is not a crucial factor any longer, largely due to the rapid advance of logistics technology. Infrastructure and country adjacency are usually also considered as part of logistics costs (Bougheas *et al.,* 1999). A rating of a country's infrastructure includes various factors including roads, telecommunications and business institutions etc. A higher rating indicates a better infrastructure. Better infrastructure should lead to higher trade. Country adjacency represents the common border between two countries and is believed to be an enabler for bilateral trade (Egger, 2000).

Language commonality means that two nations share a particular national language and cultural similarity, which is widely believed to affect the efficiency of international trade (Frankel, 1997). With regard to tariffs, their impact on trade flows has been extensively studied and considered as an effective tool for government to regulate import levels (Bouët et al, 2005).

In addition to the variables mentioned above, other variables that either enhance or impede trade between nations were also included in the gravity equation. It was assumed that these variables contribute to bilateral trade variations from the basic proportional relationship. For example, the dummy variables were included to indicate special relations between two trading nations, such as common membership in a

FTA (Limao and Venables, 1999). This study took a US perspective and included APEC, NAFTA, and WTO in the analysis.

In summary, the proposed gravity equation of US technical textile export to its 15 major trading nations is specified as follows:

$$ln(EX_{ij}) = \alpha + \beta_1 ln(USGDP_j) + \beta_2 ln(GDP_i) + \beta_3 ln(USGDPPC_j) + \beta_4 ln(GPDPC_i) + \beta_5 ln(D_{ij}) + \beta_6 ln(POP_i) + \beta_7 PGRATE_i + \beta_8 ln(USPOP_j) + \beta_9 USPGRATE_j + \beta_{10} INFRAS_i + \beta_{11} CA_{ij} + \beta_{12} LC_{ij} + \beta_{13} TARIFF_{ij} + \beta_{14} APEC_i + \beta_{15} NAFTA_i + \beta_{16} WTO_i + e_{ij} \quad (2)$$

Where, *i* represents the trading partners of US, *j* denotes US variables; α = gravity equation intercept term; $\ln(EX_{ij})$ = Log of US technical textile export value in US$ mn to 15 major trading nations, $\ln(USGDP_j)$ =Log of GDP PPP of US, in US$ mn; $\ln(GDP_i)$ = Log of GDP PPP of US trading partners, in US$ mn; $\ln(USGDPPC_j)$ = Log of US GDP PPP per capita, in US$; $\ln(GDPPC_i)$ = Log of GDP PPP per capita of US trading partners, in US$; $\ln(D_{ij})$ = Log of the geographic distance between US and its trading partners; in mile; $\ln(POP_i)$ = Log of the population of the US trading partners; $PGRATE_i$ = the population growth rate of the trading partners of the US; $\ln(USPOP_j)$ = Log of US population; $USPGRATE_j$ = the population growth rate of the US; $INFRAS_i$ = infrastructure degree of US trading partners; $CA_{ij}$ = country adjacency, A dummy variable with a value of 1 if nation has common border with US, 0 otherwise; $LC_{ij}$ = language commonality, A dummy variable with a value of 1 if nation has common language with US, 0 otherwise; $TARIFF_{ij}$ = the tariff that the US imposes on products from trading partners; $APEC_i$ =A dummy variable with a value of 1 if importers are members of Asia-Pacific Economic Cooperation, 0 otherwise; $NAFTA_i$ =A dummy variable with a value of 1 if importers are members of the North American Free Trade Area, 0 otherwise; $WTO_i$ =A dummy variable with a value of 1 if importers are members of the World Trade Organization, 0 otherwise; $e_{ij}$ = the error term.

Since compared to apparel-related textile production technical textile manufacturing is usually considered to be a relatively capital-abundant and technology-intensive activity and the demand is driven by the size and development of economy, it was predicted that the US technical textile export would be positively correlated with the GDPs and per capita GDPs of the US and its trading partners. As proxies of size of country and technical textile demand, the US technical textile export was predicted to have positive relationships with the populations and population growth rates of the US and its trading partners. With regard to geographic distance, a historical trend shows geographic distance has a statistically significant and negative impact on trade as transportation costs and convenience favor closer relationships and sourcing. The US technical textile export was predicted to be negatively correlated with geographic distance between the US and its trading partners.



Tariffs set by the importing countries on the US were expected to have a negative relationship with the US technical textile export. Infrastructure level of the US trading partners acts as a trade facilitator and, hence, was expected to possess a positive impact on the US technical textile export. In the same fashion, country adjacency and language commonality were expected to positively influence US technical textile export.

As to the common membership including APEC, NAFTA, and WTO, it was expected that such common memberships with the US would positively affect technical textile export to these countries. These three trade agreements and organizations were selected because they are the most frequently investigated trading groups for the US and would test the common and non-membership influences on trade flows between the US and its major trading partners.

### 3.2 Assessment of US technical textile trade performance

After the gravity equation for the US technical textile export was specified, it was further utilized to calculate the projected export value ($P_i$) from the US to its trading partners. In order to assess the US technical textile export performance, the relative difference index (RDI) of bilateral trade was introduced, which is defined as $RDI_i = 100 \times$ [actual trade ($A_i$) − projected trade ($P_i$)]/ [actual trade ($A_i$) + projected trade ($P_i$)]. (Chen, 2008) The popularity of the RDI measure is its relative simplicity, its ability to utilize comparable data sets, such as SITC-based trade data for the analysis, and its dependability as an indicator of actual changes in trade performance. $RDI_i$ varies between −100 and +100. Positive $RDI_i$ indicates relatively high trade performance while negative $RDI_i$ reveals relatively low trade performance. $RDI_i$ that falls within +/- 5 suggests that the position is close to neutral. The larger the $RDI_i$ is, the better performance the US technical textile export achieves. Otherwise, more attention need to be paid and appropriate actions could be taken by the industry and US government to strengthen the export competitiveness.

### 3.3 Data sources

The availability of technical textile trade data is problematic since there is neither a complete nor a universally accepted definition of technical textiles that is incorporated into official statistics. However, a review of literature from renowned textile organizations (e.g., Fiber Organon, Textile Institutes, and David Rigby Associate) and expert judgment were used to identify product categories from the Standard International Trade Classification (SITC) data set that were comprised wholly or chiefly of technical textiles. The four digit level SITC (Revision 3) was selected as providing the best definition of technical textile products. Table 4 lists the four digit product classifications that were identified by this method.

**Table 4. Major technical textile commodities**

| Commodity code | Definition |
|---|---|
| SITC 6545 | Woven fabrics of jute or other textile bast fibers (other than narrow or special fabrics) |
| SITC 6546 | Woven fabrics of glass fiber (including narrow fabrics) |
| SITC 6561 | Narrow woven fabrics (other than labels, badges, etc.); narrow fabrics consisting of warp without weft assembled by means of an adhesive |
| SITC 6562 | Labels, badges and similar articles of textile materials, in the piece or strips, etc., not embroidered |
| SITC 6571 | Felt, whether or not impregnated, coated, covered or laminated, n.e.s. |
| SITC 6572 | Nonwovens, whether or not impregnated, coated, covered or laminated, n.e.s. |
| SITC 6573 | Textile fabrics and products coated or impregnated, n.e.s. |
| SITC 6574 | Quilted textile products in the piece composed of one or more layers of textile materials assembled with padding, n.e.s. |
| SITC 6575 | Twine, cordage, rope and cables, and manufactures thereof (e.g., fishing nets, ropemakers' wares) |
| SITC 6577 | Textile wadding, wicks, fabrics and articles for use in machinery or plant |
| SITC 6578 | Rubber thread and cord, textile covered; yarns of specified |
| SITC 6581 | Sacks and bags of textile materials used for packing goods |

| | |
|---|---|
| SITC 6582 | Tarpaulins, awnings and sun blinds; tents; sails for boats, sailboards or landcraft; camping goods |

Source: UN Comtrade SITC Rev. 3 database.

Export data was obtained from the UN Comtrade database SITC Revision 3 for the years 1996 to 2006. This period was selected as being long enough to permit longer-term trends to be identified, and based on the availability of a complete data set for each of the selected products and for each of the selected trading partners. The data analysis was conducted at an aggregate level.

The Central Intelligence Agency's (CIA) World Factbook provided information on GDP, per capita GDP, population, population growth rate, and language commonality. Information on the level of each country's infrastructure development was obtained from World Development Indicators (WDI). The tariff information was compiled from the office of US Trade Representative (USTR) and the US trading partners' government websites. The tariffs for technical textiles were measured in an aggregate level. Indo distance (http://www.indo.com/distance/) provides the information for geographic distance between the capitals of US and its trading partners and Nation Master (http://www.nationmaster.com/index.php) has the information on country adjacency. The common membership of a trading bloc or organization and its details are available on the public websites of various organizations including WTO, APEC and NAFTA.

## 4. RESULTS AND ANALYSIS

Table 5 presents the exports of US aggregate textiles and technical textiles between 1996 and 2006. Over this period, the weights of technical textiles in the US textile exports have been continuously increasing from 25.6 percent in 1996 to 31.8 percent in 2006. The relatively rapid growth of US technical textile export has substantially offset the slowdown shown in its apparel related textile and home furnishing exports. The total US technical textile export hit its record high at $4.03 billion in 2006, a nearly 100 percent increase from 1996.

**Table 5. US aggregate textile and technical textile exports, 1996 - 2006**

| | Aggregate textiles (US$ bn) | Index | Technical textiles (US$ bn) | Index | % of Aggregate textiles |
|---|---|---|---|---|---|
| 1996 | $8.01 | 100 | $2.05 | 100 | 25.6% |
| 1997 | $9.19 | 115 | $2.46 | 120 | 26.8% |
| 1998 | $9.20 | 115 | $2.45 | 120 | 26.6% |
| 1999 | $9.50 | 119 | $2.58 | 126 | 27.2% |
| 2000 | $10.95 | 137 | $2.80 | 137 | 25.6% |
| 2001 | $10.47 | 131 | $2.87 | 140 | 27.4% |
| 2002 | $10.66 | 133 | $2.98 | 145 | 28.0% |
| 2003 | $10.89 | 136 | $3.22 | 157 | 29.6% |
| 2004 | $11.99 | 150 | $3.52 | 172 | 29.4% |
| 2005 | $12.38 | 155 | $3.74 | 182 | 30.2% |
| 2006 | $12.67 | 158 | $4.03 | 197 | 31.8% |

Source: UN Comtrade SITC Rev.3.

Details of the 15 major countries importing technical textiles from the US in 1996 and 2006 are shown in Appendices A and B. Due to the volume of involved data, only selected independent variables at the beginning year 1996 and ending year 2006 are included in the Appendices. These 15 major trading partners accounted for around 78% US technical textile export with a modest variation between 1996 and 2006. The list of leading importers is dominated by a combination of traditional industrialized nations, newly booming economies and countries that are located close to the US in the Americas. In terms of the size of their economies and populations, there is a wide variation with larger and smaller countries being important. In terms of per capita GDP, the list comprises primarily high and high-middle income nations (World Bank Country Classification), with only China and Dominican Republic, being prominent importers from low-middle income nations. With regard to common membership of trade groups, most nations have shared common membership with the US in at least one organization or FTA.

### 4.1 Specified gravity equation

In order to estimate the gravity equation, OLS regression with a backward elimination method was employed. The multicollinearity and insignificant independent variables were dropped from the equation in the procedure of backward elimination. This procedure was executed until the effects of multicollinearity were eliminated and all the independent variables were significant at a *p*-value < 0.05. Thus, the final gravity equation contains all the significant parameters. Tariff variables showed high correlations with common membership of trade organizations, and US per capita GDP was highly correlated with US GDP. The tariffs facing a US trading partner are largely dependent on its trade relationship with the US, namely its common membership of trade organizations or FTAs. Therefore, tariff level could be represented by common trade organization or FTA membership. In order to identify the individual impacts of interested common trade organization or FTA memberships on the US technical textile export, the tariff variable was dropped from the equation. In a similar fashion, the US per capita GDP was not included in the tested gravity equation.

Overall, the F-value of the final gravity equation is 30.745 which is statistically significant (*p*-value<0.001). The corresponding R square is 0.759 and adjusted R square is 0.748. Thus, the majority variation of US technical textile export could be accounted for by the final gravity equation, which is satisfactory. The final gravity equation is as follows.



$$\ln(EX_{ij}) = -7.360 + 2.136\ln(USGDP_j) + 0.327\ln(GDPPC_i) + 0.224\ln(POP_i) - 0.220\ln(D_{ij}) + 0.002INFRAS_i + 1.137NAFTA_i + e_{ij} \quad (3)$$

The detailed results of the OLS regression analysis are summarized in Table 6. According to the results, US GDP has a positively significant relationship with the US technical textile export. The result shows that with a 10 percent increase in the US GDP there would be a 21.36 percent growth in the value of US technical textile export. This conforms to the theoretical expectation and previous studies (Bougheas et al., 1999), that a higher level of GDP in the exporting country would create a bigger production capacity resulting in a larger supply and economy of scales for exports. In a similar fashion, the value of US technical textile export would increase 3.27 percent as induced by a 10 percent increase in per capita GDP of US trading partner. This result is consistent with the conclusion (Gros and Gonciarz, 1996) that for a given overall GDP a country with a higher per capita GDP would trade more intensively than a poorer country.

The significant coefficient for the population of US trading partners shows that with a 10 percent increase in the population of US trading partners, there would be a 2.24 percent increase in the value of US technical textile export. This relationship meshes with previous studies (Linnemann, 1966), as an indicator of country size, the increasing population creates bigger demand and promotes trade. Compared to the impact of US GDP on its technical textile export, the degree of significance of per capita GDP and population of US trading partner s are much lower.

**Table 6. Results of OLS regression analysis for the proposed gravity equation**

| Variable | Expected Sign | Coefficient | S.E. | *t*-value | *p*-value |
|---|---|---|---|---|---|
| Intercept | +/- | -7.360 | 2.765 | -2.662 | 0.009 |
| $\ln(USGDP_j)$ | + | 2.136 | 0.406 | 5.267 | <0.001 |
| $\ln(GDPPC_i)$ | + | 0.327 | 0.162 | 2.019 | 0.045 |
| $\ln(POP_i)$ | + | 0.224 | 0.053 | 4.226 | <0.001 |
| $\ln(D_{ij})$ | - | -0.220 | 0.081 | -2.723 | 0.007 |
| $INFRAS_i$ | + | 0.002 | 0.004 | 5.231 | <0.001 |
| $NAFTA_i$ | + | 1.137 | 0.063 | 18.104 | <0.001 |
| F-value of the final gravity equation | | | | 30.745 | |
| *p*-value | | | | <0.001 | |
| R square | | | | 0.759 | |
| Adjusted R square | | | | 0.748 | |

Note: significant at *p*-value<0.05 level.

With regard to geographic distance, the estimated coefficient for the distance between the US and its trading partners has a negatively significant impact on US technical textile export to the country, as predicted previously. The result shows that with a 10 percent increase in geographic distance there would be a corresponding 2.2 percent decline in the value of US technical textile export. This finding is consistent with the theoretical prediction, suggesting that greater distance tends to restrain trade flows as transport cost and convenience favor closer sources and markets (Aitken, 1973; Bergstand, 1985; Rose, 2002). This also indicates that geographic distance is still a significant hindrance for the US to export technical textiles to remote countries, although currently a large portion of US technical textile importers are West European and East Asian nations.

The status of *i* country's infrastructure affects its demand on technical textiles from the US. Better infrastructure reflects a higher level of economic development and spurs the usage of technical textiles in a variety of infrastructure related end-uses. The result shows that with a 10 percent increase of country *i*'s infrastructure level there would be a corresponding 0.2 percent ($[\exp(0.002) -1]\times 100\%$) increase in its technical textile import from the US.

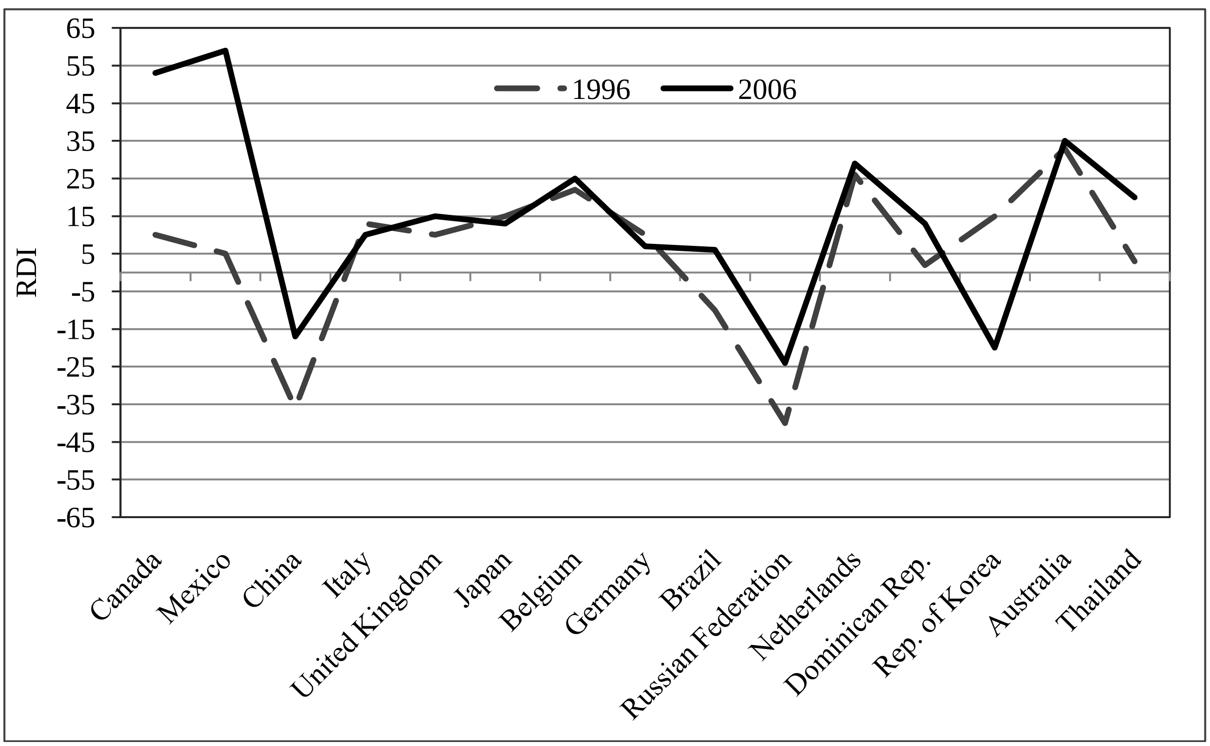


Finally, NAFTA shows a significant positive relationship with US technical textile export. NAFTA, as an exclusive FTA within the North America, played a significant role as trade creating factor for member countries by easing commodity movements. The result indicates that special trade relation between the US and Canada and Mexico is crucial and has spurred the US technical textile export to these countries with a remarkable increase at 212% ($[\exp(1.137)-1]\times 100\%$).

## 4.2 US technical textile trade performance

Figure 1 compares all calculated RDIs in technical textile export from US to its 15 major trading partners in 1996 and 2006 respectively. Overall, US exhibited a relatively higher trade performance with most high-income nations including Canada, Italy, United Kingdom, Japan, Belgium, Germany, Netherlands, and Australia with the exception of Rep. of Korea. Compared to the 1996's RDIs, the RDIs of US technical textile export in 2006 showed an upward trend with Canada, United Kingdom, Belgium, Netherlands, and Australia while the RDIs for Italy, Japan, and Germany decreased slightly although they were still above positive five. In contrast, the RDIs with Rep. of Korea fell radically from 15 in 1996 to negative 20 in 2006. The US technical textile export performance with its adjacent nations achieved phenomenal increase from the RDIs at 10 and 5 in 1996 to 53 and 59 in 2006 for Canada and Mexico respectively. Similarly, over the period, the US trade competitiveness in technical textiles with Dominican Rep. and Thailand gained apparent improvement from some neutral positions at the RDIs of two and four to upward positive positions of 13 and 20 respectively. With regard to the trade performance with the emerging economies, the RDIs revealed that the US did improve its technical textile export competitiveness with China, Russian Federation, and Brazil between 1996 and 2006, however, in 2006 US still showed relatively lower performances with China and Russian Federation and a neutral position with Brazil.

**Figure 1. RDIs in technical textile export from US to 15 major trading partners in 1996 and 2006**




Note: Belgium was Belgium-Luxembourg in 1996.

## 5. CONCLUSIONS

In the last decade, technical textiles have played an increasingly important role in the US textile economy in terms of both size and impact. In addition to a well-established domestic position, the industry has realized that the long-term growth of US technical textile sector relies on its continuous expansion in the international markets (Author *et al.*, 2005; Smith, 2001). However, the US technical textile export is a complex and dynamic activity which is influenced by a combination of factors. This research empirically investigated a wide range of factors discussed in the previous studies and identified the determinants of US technical textile export. The changes of US trade performances in technical textiles with its 15 major trading partners were further quantified by the calculated RDIs.

A number of important conclusions are drawn from this study. First, the results provide robust support for gravity model. The growing US GDP and its trading partner's per capita GDP are driving the US technical textile export, while the greater geographic distance of the trading partner from US significantly impedes the US exports to the nation. It perfectly meshes with the foundation of gravity model. A greater US GDP represents a greater production which results in a larger supply for export. In the meantime, increasing per capita GDP of US trading partner spurs the usage of technical textiles. The significance of factor - geographic distance indicates logistic cost and delivery efficiency are still major concerns for nations to outsource technical textiles. Quick response and localization/regionalization of production and supply arrangements could be winning strategy for the US technical textile companies. Another basic factor in the gravity model – the US trading partner population also shows a positive relationship with the US technical textile export, suggesting the US trading partners which have a larger size create greater demands for technical textiles and populous nations (i.e., China, Brazil, and Mexico) are more likely to import more technical textiles from US.

Secondly, the positive impact on US technical textile export from the importing country's infrastructure shows the consumption of technical textiles in these nations is fostered by their development of infrastructure (e.g., logistic/transportation system, financial system, and telecommunication/information system *etc*.). The substantial upgrading in trading partner's national infrastructure creates sustainable business opportunities for the US technical textile companies. It is particularly evident in some burgeoning economies such as China and Brazil.

Thirdly, the analysis shows that NAFTA is one of the most influential factors for the US technical textile export. The US government aiming to promote US textile export and regional economic cooperation initiated NAFTA in 1994. Although the implementation of NAFTA has been often criticized as a fatal decision for the US apparel industry with regard to the unbeatable price advantage and geographic adjacency of Mexico, the free access to the Canadian and Mexican markets was considered to be one of the biggest steps forward in strengthening the trade competitiveness of US technical textiles in the international market. Today, Mexico and Canada are the two largest consuming nations for the US technical textiles.

Finally, the trade performance analysis using RDI reveals that US competitive position in technical textiles is not simple and uniform across its major trading partners. The RDI results show that US achieved a dominating trade performance with its adjacent nations - Canada and Mexico. Over the period, US exhibited a relatively higher and more stable trade performance with most high income nations expect Rep. of Korea in contrast to most high-middle and low-middle income trading partners. It reflects that the technical textile markets in high income nations have been comparatively matured while the growth in middle income nations is just starting. These promising markets demand more attentions and investments from the US technical textile companies. In particular, the improvement of trade performance with those booming economies such as China is crucial for the long-term prosperity of US technical textile sector. This finding is consistent with the forecasts of final consumption of technical textiles by geographic region from David Rigby Associates which indicates Asia will be the largest consumption market for technical textiles.

Overall, the determinants identified from this analysis provide a better understanding of the changing patterns of US technical textile export and give researchers insights for further exploration. RDIs clearly disclose the trade performance of US technical textile sector with its major trading partners over the time period. The empirical evidence derived from this study enable government officers and industrial practitioners to make effective decisions on trade policies, investments, and export marketing.

## 6. FUTURE RESEARCH

This paper provides the springboard for further studies in the field. The possible directions for future research are presented as follows. First, additional factors could be added into the developed gravity equation to better account for the variation of US technical textile export. Second, the analysis of this study is performed at an aggregate level. The follow-up studies could be developed in the disaggregated technical textile categories to identify the impact of these factors on some specific products such as nonwovens. Lastly, some nation-specific case studies could be developed based on the findings from this research.

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## APPENDIX A

*Analysis of U.S. to its Major Trading Partners in 1996: Country Group, Technical Textile Export, GDP, GDP per Capita, Population, Distance from U.S., and Common Trade Organization/FTA Memberships*

| Countries | Country Groups | U.S. technical textile export ($ million) | GDP PPP ($ billion) | Population | GDP PPP per capita ($) | Distance from U.S. (miles) | Common membership with U.S. | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | APEC | NAFTA | WTO |
| Canada | High income | $544.9 | $639.8 | 28,434,545 | $22,760 | 2,361 | √ | √ | √ |
| Mexico | High-middle income | $350.5 | $728.7 | 93,985,848 | $7,900 | 1,182 | √ | √ | √ |
| Japan | High income | $115.8 | $25,274 | 125,506,492 | $20,200 | 6,790 | √ | x | √ |
| United Kingdom | High income | $109.7 | $10,452 | 58,295,119 | $17,980 | 3,674 | x | x | √ |
| Belgium-Luxembourg | High income | $93.1 | $181.5 | 10,081,880 | $18,040 | 3,872 | x | x | √ |
| Germany | High income | $80.3 | $13,446 | 81,337,541 | $16,580 | 4,246 | x | x | √ |
| Rep. of Korea | High income | $53.2 | $508.3 | 45,553,882 | $11,270 | 6,950 | √ | x | √ |
| Brazil | High-middle income | $36.4 | $886.3 | 160,737,489 | $5,580 | 4,726 | x | x | √ |
| Dominican Rep. | Low-middle income | $36.1 | $24 | 7,511,263 | $3,070 | 1,477 | x | x | √ |
| Australia | High income | $35.1 | $374.6 | 18,322,231 | $20,272 | 9,760 | √ | x | √ |
| Italy | High income | $30.8 | $998.9 | 58,261,971 | $17,180 | 4,501 | x | x | √ |
| Netherlands | High income | $27.3 | $275.8 | 15,452,903 | $17,940 | 3,855 | x | x | √ |
| Thailand | High-middle income | $18.8 | $355.2 | 60,271,300 | $5,970 | 8,799 | √ | x | √ |
| China | Low-middle income | $13.3 | $29,788 | 1,210,004,956 | $2,500 | 6,971 | √ | x | x |
| Russian Federation | Low-middle income | $8.5 | $721.2 | 149,909,089 | $4,820 | 4,782 | x | x | x |

Note: 1. 1996 data; U.S. GDP PPP was $67,384 billion; U.S. GDP PPP per capita was $25,850; U.S. Population was 263,814,032.
2. √ represents the trading partner has the common membership with the U.S., x otherwise.
3. Country groups are based on World Bank country classification.

**APPENDIX B**

*Analysis of U.S. to its Major Trading Partners in 2006: Country Group, Technical Textile Export, GDP, GDP per Capita, Population, Distance from U.S., and Common Trade Organization/FTA Memberships*

| Countries | Country groups | U.S. technical textile export ($ million) | GDP PPP ($ billion) | Population | GDP PPP per capita ($) | Distance from U.S. (miles) | Common membership with U.S. | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | APEC | NAFTA | WTO |
| Canada | High income | $805.6 | $1,165 | 33,098,932 | $35,200 | 2,361 | √ | √ | √ |
| Mexico | High-middle income | $1,258.8 | $1,134 | 107,449,525 | $10,600 | 1,182 | √ | √ | √ |
| Japan | High income | $141.1 | $4,220 | 127,463,611 | $33,100 | 6,790 | √ | x | √ |
| United Kingdom | High income | $113.9 | $1,903 | 60,609,153 | $31,400 | 3,674 | x | x | √ |
| Belgium | High income | $125.7 | $330.4 | 10,379,067 | $31,800 | 3,872 | x | x | √ |
| Germany | High income | $117.3 | $2,585 | 82,422,299 | $31,400 | 4,246 | x | x | √ |
| Rep. of Korea | High income | $48.4 | $1,180 | 48,846,823 | $24,200 | 6,950 | √ | x | √ |
| Brazil | High-middle income | $39.6 | $1,616 | 188,078,227 | $8,600 | 4,726 | x | x | √ |
| Dominican Rep. | Low-middle income | $98.9 | $73.7 | 9,183,984 | $8,000 | 1,477 | x | x | √ |
| Australia | High income | $35.3 | $666.3 | 20,264,082 | $32,900 | 9,760 | √ | x | √ |
| Italy | High income | $36.7 | $1,727 | 58,133,509 | $29,700 | 4,501 | x | x | √ |
| Netherlands | High income | $36.8 | $512 | 16,491,461 | $31,700 | 3,855 | x | x | √ |
| Thailand | High-middle income | $46.2 | $585.9 | 64,631,595 | $9,100 | 8,799 | √ | x | √ |
| China | Low-middle income | $304 | $10,000 | 1,313,973,713 | $7,600 | 6,971 | √ | x | √ |
| Russian Federation | Low-middle income | $28.7 | $1,723 | 142,893,540 | $12,100 | 4,782 | x | x | x |

Note: 1. 2006 data; U.S. GDP PPP was $12,980 billion; U.S. GDP PPP per capita was $43,500; U.S. Population was 298,444,215.
2. √ represents the trading partner has the common membership with the U.S., x otherwise.
3. Country groups are based on World Bank country classification.