An investigation of Chinese textile firms' R&D performance

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Abstract:

The purpose of this study was to enhance the understanding of Chinese textile manufacturers' research and development (R&D) performance. Specifically, the study empirically examined (a) current trends of R&D activities in the Chinese textile industry; (b) R&D intensity among Chinese textile firms and determinants of its variation; and (c) R&D effectiveness among Chinese textile firms and factors impacting it. The research results are based on survey data from 768 textile manufacturers located in a Southeastern County with a mature textile and apparel cluster. Logistic regression was employed for data analyses. The results showed that R&D investment levels among Chinese textile firms are relatively low in comparison with advanced textile industries in developed countries. Chinese textile firms with international operations had a higher R&D intensity, or investment level, than those without international operations. Foreign ownership and financial resources were not significant predictors of the firm's R&D intensity. Chinese textile firms that relied on acquiring new machinery/technology and were involved in internal R&D activities were more likely to have higher R&D effectiveness, which translated into positive profit margin. The R&D intensity did not contribute significantly to R&D effectiveness. To offset increasing production cost and sustain its diminishing low-cost comparative advantage, the Chinese textile industry's next step is to focus on R&D. The study offers strategic directions to the industry and policy makers that might be helpful to keep the industry competitive in the global marketplace.

Keywords: China | textile industry | research | development

Article:

Introduction

China is the world largest supplier of textiles (Organisation for Economic Co-operation and Development [OECD], 2004). However, the Chinese textile industry currently faces several challenges, including rising cost of raw materials, labor, and energy (Yang, He, & Zhang, 2010). To address these challenges, Chinese textile manufacturers must develop new strategies to

remain competitive and responsive to changes in the global marketplace (Lane & Probert, 2006). One of the promising strategies for China's textile manufacturing sector is to learn how to deploy and utilize research and development (R&D) resources effectively (Jefferson, Bai, Guan, & Yu, 2006). Scholars have projected that over the long term, the Chinese textile industry's performance will depend on its ability to innovate, acquire, and diffuse new technologies (Jefferson et al., 2006, Yang et al., 2010).

Despite the strategic importance of R&D for the future of the Chinese textile industry, there is virtually no empirical research on Chinese textile firms' current R&D activities. The purpose of this study was to enhance the understanding of Chinese textile manufacturers' R&D performance, particularly in relation to R&D intensity and effectiveness. R&D intensity indicates the firm's R&D investment level (Spithoven, Clarysse, & Knockaert, 2010). R&D effectiveness refers to the contribution of R&D activities to firms' financial performance (Christoffersen, 2002; Cohen, Levin, & Mowery, 1987). Specifically, the study aims to empirically examine (a) current trends of R&D activities in the Chinese textile industry; (b) R&D intensity among Chinese textile firms and determinants of its variation; and (c) R&D effectiveness among Chinese textile firms and factors impacting it.

Two main contributions of this study are useful for textile industry policy makers as well as individual textile firms, both within and outside of China. First, even though R&D intensity and effectiveness have been frequently studied in the context of various industries, empirically based knowledge about the textile industry is sparse (Christoffersen, 2002). This study fills this gap and enhances our understanding of issues related to textile firms' R&D deployment. The results of this research can assist textile firms in devising effective R&D strategies, for example, selecting appropriate R&D approaches and R&D investment levels.

Second, an examination of the R&D issue in the Chinese textile industry is timely and important, given that R&D is predicted to become a growing strategic trend for maintaining industry competitiveness (Yang et al., 2010). The findings of the study help project the future of the Chinese textile industry during its critical transition period. Given the global influence of the Chinese textile industry, such insights are important for industry policy makers in China and the rest of the world.

The next section of the article reviews extant R&D research. Based on the perspective of resource-based (RB) theory, the authors developed a series of hypotheses related to R&D effectiveness and R&D intensity in the Chinese textile industry. The methodology section discusses data collection and analyses. The following section presents a description of the survey sample and results of hypotheses testing. Conclusions and implications of the study are the foci of the last section.

Literature review

RB Theory and R&D

RB theory views a firm as a unique collection of tangible and intangible resources, which allow the firm to operate in a cost-efficient manner and contribute to the firm's competitive advantage (Barney, 1991; Sharma & Erramilli, 2004). For example, Park and Dickson (2008) applied the RB conception in their investigation of apparel and footwear firms' strategic orientation in relation to labor management. The theory perceives a firm's R&D as an important form of intangible resources, which contributes to firm competitiveness and performance

(Oerlemans & Meeus, 2001). According to the theory, effective development and utilization of a firm's R&D are associated with the firm's possession of four resources: (a) human resources, which represent R&D related-knowledge possessed by individuals within the firm; (b) organizational capital, which refers to organizational culture and R&D initiatives of the firm for exploitation and improving R&D capacity; (c) relational capital, which addresses the firm's relationship with suppliers, customers, external experts, regulatory bodies, and research institutes for nurturing R&D competencies; and (d) monetary capital, which includes any financial assets that can be disbursed for R&D activities (Oerlemans & Meeus, 2001; Pike, Roos, & Marr, 2005). Relationships between these resources and textile firms' R&D performance are explicated in the following section of the article.

R&D in the Textile Industry

The textile industry's scope includes production of fibers, yarns, fabrics, and other textile products used in the apparel and other industries. In general, R&D in textile industries refers to development, diffusion, and adoption of innovative textile products or manufacturing processes (OECD, 2004). R&D can be examined at the levels of individuals, R&D labs (public and private research organizations), and firms (Lee, Son, & Lee, 1996), with the last being the focus of this study. In line with RB theory, a central goal of textile firms' R&D is to ultimately transfer the R&D results into competitive advantage and improve firm performance (Shin, Kraemer, & Dedrick, 2009).

Textile firms' R&D can be distinguished between product-related or production-related activities (Kaufmann & Kroszner, 2002; OECD, 2004). Product-related R&D is dominated by developing and introducing innovative technical textiles (Kaufmann & Kroszner, 2002) and "green" products (Perks & Jeffery, 2006). Technical textiles are defined as "textile materials and products manufactured primarily for their technical and performance properties rather than aesthetic or decorative characteristics" (OECD, 2004, p. 1). Product-related R&D activities can enhance textile firms' competitiveness beyond price-based competition by achieving higher added value and getting a share of niche markets.

Production-related R&D efforts are directed to the manufacturing processes for achieving higher productivity, production versatility, and product quality by installing advanced equipment and implementing innovative processes (OECD, 2004). Production-related R&D enables textile firms to remain competitive by enhancing their ability to offer attractive prices for quality textile products (Pegels & Thirumurthy, 1996).

As a national textile industry matures (as indicated by more sophisticated production techniques), the industry's dependence on R&D increases (Fedderke & Schirmer, 2006). Facing pressure from low-cost textile producers (often located in developing countries), advanced textile industries are forced to rely on R&D to attain higher value-added output and greater productivity in order to remain competitive (Pegels & Thirumurthy, 1996). This observation is also supported by RB theory—R&D advancement requires various resources, such as human and financial, which are more readily available in developed countries, where mature textile industries are typically located (Pike et al., 2005). Since the Chinese textile industry has been primarily associated with lower value-added and labor intensive manufacturing, the contribution of R&D to its competitiveness is thus expected to be lower in comparison with mature textile industries in advanced economies, for example, Japan, Germany, and the United Kingdom (Yang et al., 2010).

Nevertheless, continuing industry integration, improved production capability, and

increasing productivity as well as rising production costs indicate that the Chinese textile industry is moving away from low value-added to higher value-added activities (OECD, 2004), which suggests that the industry will increasingly emphasize R&D strategies (Fedderke & Schirmer, 2006). The Chinese textile industry's recent surge in the production of technical textiles (accounted for 15% of total U.S. technical textiles' imports in 2003) indicates an emerging R&D trend in the industry (OECD, 2004). In addition to R&D initiatives among individual Chinese textile firms, there is unprecedented support from the government to embrace R&D development in the Chinese textile industry (Linton, 2008).

R&D Intensity and its Determinants

Intensity represents the level of a firm's investment in R&D activities, which is calculated as the ratio of a company's R&D expenditure to the company's total sales (Yeh, Chu, Sher, & Chiu, 2010). R&D investment levels differ among firms within an industry due to various external and internal factors. Drawing on RB theory and extant research, three factors were identified that might have an impact on Chinese textile firms' R&D intensity, namely, involvement in international operations, foreign ownership, and financial resources (Kumar & Saqib, 1996; Lee & Noh, 2009; Oerlemans & Meeus, 2001; Pike et al., 2005).

Involvement in International Operations

RB theory suggests that a firm's organizational culture and market orientation can either forge or depress the firm's R&D activities (Pike et al., 2005). Involvement in international operations indicates a firm's market orientation tactics. Firms involved in international markets "must apprehend, share and assimilate new knowledge in order to compete and grow in markets in which they have little or no previous experience" (Autio, Sapienza, & Almeida, 2000, p. 11). There is a gap between textile manufacturers in China and those in advanced economies, in terms of both new product development and manufacturing processes (Yang et al., 2010). To meet the demands of more sophisticated international customers, Chinese textile firms involved in international operations tend to have greater pressure and initiatives for product innovation and continual updates of manufacturing processes (Hall & Oriani, 2006). Therefore, the need for R&D activities as an approach to knowledge augmentation is expected to be higher for firms with international operations.

> Hypothesis 1: Involvement in international operations is positively related to R&D intensity of Chinese textile firms.

Foreign Ownership

In addition to international operations, a firm's foreign ownership can also influence its organizational culture (Abernathy, Volpe, & Weil, 2004; Liu & Wang, 2003; Pike et al., 2005). Textile firms in developed countries generally have a superior technology level than their Chinese counterparts (OECD, 2000). Consequently, a Chinese textile firm with foreign ownership is more likely to adopt advanced technology from the foreign partner firm, which in turn increases the firm's level of R&D activities (He, 2004; Jefferson, Hu, Guan, & Yu, 2003). Furthermore, one of foreign textile firms' motivations for investing in China is to facilitate

outsourcing of textile products, which encourages them to enhance local firms' R&D level to produce advanced products for international customers (Co, 2000).

> Hypothesis 2: Foreign ownership is positively related to R&D intensity of Chinese textile firms.

Financial Resources

RB theory states that a firm's R&D activities depend on the availability of the firm's financial resources (Pike et al., 2005). More specifically, firms with more financial resources tend to invest more in R&D because of (a) more funds available for spending on R&D and (b) higher spending on areas that are complementary to R&D activities, such as developing their own R&D teams (Kumar & Saqib, 1996). This suggests that a firm's R&D investment level should increase with the firm's financial resources (Lee & Sung, 2005). Therefore, Chinese textile firms with greater financial resources are expected to have higher investment in R&D.

> Hypothesis 3: Financial resources are positively related to R&D intensity of Chinese textile firms.

R&D Effectiveness

Although it is commonly agreed that investment in R&D can enhance a firm's performance, it is important to empirically measure actual contribution of R&D activities to the firm's overall performance, which is referred to as R&D effectiveness (Sen & Rubsentein, 1990). Assessment of R&D effectiveness will help to determine whether R&D investments are justified and maximize a firm's performance (Lee et al., 1996). However, there is no universally accepted method for measuring R&D effectiveness. Most approaches have relied on measuring either a firm's improvement in productivity (Christoffersen, 2002) or financial performance (Andras & Srinivasan, 2003). In this study, financial performance operationalized as annual profit margin was selected for measuring Chinese textile firms' R&D effectiveness because (a) it is a more direct reflection of firm performance and (b) there are "substantial flaws" associated with measuring productivity (Szakonyi, 1994, p. 1). The following determinants of Chinese textile firms' R&D effectiveness were examined: R&D intensity, external R&D, and internal R&D (Pike et al., 2005; Yeh et al., 2010).

R&D Intensity

R&D intensity represents the level of a firm's financial investment in R&D activities in relation to the firm's total sales (Yeh et al., 2010). The relationship between R&D intensity and R&D effectiveness has been an area of interest for both practitioners and researchers (Christoffersen, 2002). There is empirical evidence that a firm's R&D investment has a positive impact on its performance (Lee et al., 1996). According to RB theory, R&D expenditure is a form of investment in intangible assets with positive effects on a firm's capability to create future growth (Pike et al., 2005). A higher level of R&D tends to improve firm performance through (a) acquiring advantages in product innovation; (b) facilitating product differentiation; and (c) increasing productivity (Andras & Srinivasan, 2003).

Hypothesis 4: R&D intensity is positively related to R&D effectiveness of Chinese textile firms.

External R&D

A company's involvement in R&D is generally designated as internal or external. Internal R&D includes in-house R&D (i.e., R&D conducted within a firm's R&D department) and R&D alliances (i.e., R&D conducted between the firm and its competitors, suppliers, customers, distributors, or research institutes; Hu, Jefferson, Guan, & Qian, 2003). External R&D activities refer to the acquisition of existing innovations through purchasing technology, patents, or licensing agreements (Tsai & Wang, 2008). A special case of external R&D is technology imitation, which could be based on the process of reverse engineering (discovering technological principles of a product/machinery/process through analysis of its structure, function, and operation) or knowledge spillover (Hu et al., 2003). In the textile industry, imitation through knowledge spillover occurs when foreign investors bring in an advanced technology or product to subsidiaries in developing countries, and, with time, the innovation is appropriated by local textile firms with no or minor costs (Onyeiwu, 1997).

According to RB theory, textile firms' selection of R&D types depends on available human, relational, and financial resources (Pike et al., 2005). For example, firms are required to have greater financial and human resources to implement internal R&D in comparison with external R&D. Furthermore, relational resources (i.e., a firm's relationship and networking with universities, government, or suppliers) are necessary for R&D alliances (Pike et al., 2005). Imitation, which requires less financial and human resources, is often preferred by firms in the Chinese textile industry because Chinese textile firms' (a) innovative capacity is lagging relative to those in developed nations and (b) financial resources are restricted to non-R&D-related activities (Onyeiwu, 1997; Yang et al., 2010).

Despite its low-cost benefits, imitation has certain shortcomings. First, product imitation takes time, which causes a delayed market presence that subsequently leads to lower product prices and minimal profits (He, 2004). Second, reliance on imitation impairs firms' long-term capability in product differentiation (He, 2004). Third, textile firms' machinery imitation can also be problematic, for example, the principles of a target technology cannot be easily deduced by reverse engineering (Kim & Kim, 1998). Accordingly, in comparison to R&D imitation, R&D acquisition is more advantageous for new products' speed to market, product differentiation, and productivity improvement, all of which are critical for textile firms to remain competitive and profitable (Pegels & Thirumurthy, 1996). This indicates that R&D acquisition is expected to contribute more to R&D effectiveness than R&D imitation.

Hypothesis 5: Type of external R&D, acquisition, is positively related to R&D effectiveness of Chinese textile firms.

Internal R&D

An important concept related to R&D is a firm's absorptive capability that stresses the importance of the firm's human resources to effectively identify, assimilate, and exploit externally acquired innovations (Cohen & Levinthal, 1990; Pike et al., 2005; Veugelers, 1997). Internal R&D activities (e.g., in-house R&D and R&D alliances) are regarded as the primary

approaches for companies to establish such absorptive capability (Helble & Chong, 2004). For example, results from Sen and Rubsentein's (1990) study indicate that internal R&D improves firms' R&D absorptive capability, for example, by enhancing firms' evaluation, preparation, and actual adoption of externally acquired technology. It is thus logical to posit that a Chinese textile firm's internal R&D facilitates greater and more successful implementation of external R&D activities, which, in turn, improves the firm's R&D effectiveness.

Hypothesis 6: Internal R&D is positively related to R&D effectiveness of Chinese textile firms.

Method

Data Collection

In this study, the researchers used secondary data collected for a research project organized by a county government in southeastern China. The county hosts a well-developed textile and apparel industrial cluster, consisting of thousands of textile and apparel firms. To gain an updated understanding of textile and apparel manufacturing firms in the cluster with the goal of its further development, the county government appointed a research team in 2009 that was in charge of questionnaire development, data collection, and final report preparation. One section of the questionnaire was dedicated to firms' R&D operations. The authors were given access and permission to use the data from the R&D section for this study.

The questionnaires were distributed by government official representatives through on-site visits to local textile and apparel manufacturing firms. Questionnaires were given to and filled out by personnel at the middle management level or above. Respondents were informed that participating in the study was voluntary and anonymous. The same government representatives collected questionnaires a week later during another on-site visit. A total of 2,500 questionnaires were distributed. A total of 1,086 were collected, a 53% response rate. A relatively high response rate can be explained by the county government's administration of the research project. Out of the total returned questionnaires, 768 were completed by textile manufacturers and usable, resulting in a usable return rate of 31%. These 768 surveys thus constituted the sample for this study.

Instrument Development

The research instrument used in this study was a self-administered questionnaire with five main sections measuring the following: (a) R&D intensity, (b) R&D effectiveness, (c) financial resources, (d) foreign ownership, (e) involvement in international operations, (f) internal R&D, and (g) external R&D type. To measure the research constructs, the authors relied on existing literature. Except for financial resources, all variables in the study were operationalized as categorical and defined as follows.

R&D intensity was operationalized as an R&D investment expenditure percentage of total sales (Yeh et al., 2010). The scale from <1.0%, 1.0–1.9%, 2.0–2.9%, 3.0–4.9%, to >4.9% was employed. Based on the literature, firms that invest 3.0% or more of total sales in R&D are considered to be firms with high R&D intensity (European Commission, 2008; Yang et al., 2010). The data were, therefore, grouped into binary categories of "high R&D intensity" (3.0%

or greater) and "low R&D intensity" (less than 3.0%).

R&D effectiveness was operationalized as a firm's profit margin in the previous fiscal year (Andras & Srinivasan, 2003). Respondents indicated whether their company had a positive profit margin, a negative profit margin, or breakeven for the last fiscal year. The data were then grouped into binary categories of "high R&D effectiveness" (positive profit margin) and "low R&D effectiveness" (breakeven or negative profit margin).

For the continuous variable financial resources, surveyed firms were asked to indicate their registered capital[1] in monetary value, which is the total capital firms have for operating the business. In China, the government requires all firms to register their capital when they apply for corporate status and to update the registered figure when it is changed (SAIC, 2012). Therefore, registered capital is appropriate for measuring firms' financial resources.

For foreign ownership, firms were asked to check appropriate categories of their ownership. Firms that were wholly owned by a foreign company, or were a joint venture with a foreign company were grouped together under "foreign ownership," with the remaining firms constituting a second group under "without foreign ownership."

To measure involvement in international operations, respondents checked all categories of international operations in which their firms were involved, with an additional category of no international operations. Based on the responses, all firms were categorized into two groups: "with international operations" and "without international operations," creating a dichotomous variable.

Similarly, to assess firms' internal R&D, respondents indicated all appropriate types of their internal R&D (collaboration with other companies, collaboration with universities and research institutes, collaboration with clients or suppliers, outsourcing R&D) with an additional category of no internal R&D. A dichotomous variable of internal R&D was created "firms with internal R&D" and "firms without internal R&D."

For external R&D type, respondents indicated the main type of their external R&D by choosing a single option among the choices listed. The choices were imitation of new products, licensing, purchasing equipment, purchasing patents, purchasing techniques or blueprints, and others. Hu et al.'s (2003) and Tsai and Wang's (2008) studies were borrowed for identifying these external R&D types. The data were categorized into two groups, "imitation" and "acquisition," based on whether respondents chose imitation or purchasing as the primary type of external R&D. Respondents were required to provide specifications if others was selected, which was used to determine group membership.

For descriptive purposes, additional information was obtained from the government data set, including firms' background information, such as years in operation, qualitative self-assessment of firms' current technology level (i.e., as compared to other firms in the industry), and other characteristics, such as R&D barriers.

Data Analysis and Results

Sample Characteristics

Forty-one percent of the firms in the sample were engaged in manufacturing fabrics for the apparel industry, 23% specialized in the finishing sector, 12% produced yarn, 9% manufactured textiles for home furnishings, and the rest (19%) were engaged in at least two of the above areas. The average registered capital of all the firms in the sample was close to U.S. $1

million. Among all the firms in the sample, only 2% reported that they produced higher end goods, nearly 60% of the firms manufactured medium- to high-end products, and 38% produced low- to medium-end goods. Thirty-five percent of the firms manufactured products only for the Chinese market, whereas the rest of the sample (65%) had at least some involvement in producing goods for overseas markets. In the last fiscal year for which statistics are available (2008–2009), slightly more than half the sample (55%) reported a positive profit margin, 24% of the firms reported that they broke even, and close to 21% of the firms saw a negative profit margin.

R&D Intensity

A majority of the firms in the sample (64%) invested less than 2.0% of their sales in R&D, 19% of the firms invested between 2.0% and 2.9%, and only 17% of the firms invested 3.0% or more of sales in R&D. These numbers indicate that the level of Chinese firms' R&D investment is lower than R&D investment levels among textile firms in developed countries, where the average falls between 2.0% and 5.0% of total sales (European Commission, 2008). Roughly half of the sample, 48%, perceived that their firms' current technology level was higher than the Chinese textile industry's average. Another 48% estimated their technology level as average, and only 4% of the firms considered their current technology levels as lagging behind the average level of the Chinese textile industry. Even though the results indicated a relatively low level of R&D intensity, the majority of the firms perceived that their current technology level was either at the top of the industry (48%) or at least matched the industry standards (48%).

R&D Types

In the sample, 95% of the firms were involved in some type of external R&D, which was considerably higher than the percentage of firms involved in internal R&D (75%). Twenty-six percent of the firms took on both external and internal R&D activities. The greater involvement of Chinese textile firms in external, rather than internal, R&D is in line with the existing literature which indicates that firms in less advanced textile industries tend to follow a business strategy of "economizing in the area of R&D" by focusing on acquisition of technology and knowledge made available by developed countries (Singleton, 1997, p. 48). In contrast, R&D activities in advanced textile industries tend to concentrate on developing innovative technology within firms' own R&D departments, thus fully exploiting benefits from successful R&D activities (Love & Roper, 2002). However, the percentage of Chinese textile firms engaged in internal R&D was higher than in other developing countries (e.g., 60% in Tunisia; Karray & Kiraa, 2008). This fact may suggest that the Chinese textile industry might be shifting away from low-cost production and gearing up its R&D competence, indicating the industry's increasing maturity.

About half of the sample, 46%, invested in purchasing machinery or technology as the primary external R&D activity, followed by imitation of products and processes, 23%. The reported percentage (23%) of imitation is likely to be lower than the actual number of Chinese textile firms involved in imitation, which is believed to be significantly higher (Bin, 2008; Yang et al., 2010). Only 8% of the firms adopted licensing as the primary channel for external R&D. Licensing is considered a more sophisticated activity in comparison with other types of external R&D because it involves higher monetary costs and greater involvement of human and

organizational resources (Daim & Kocaoglu, 2008).

One fourth of the sample (25%) was not involved in internal R&D. Among the remaining firms, 22% used in-house R&D as the primary approach for conducting internal R&D. Among the different types of R&D alliances, cooperation with suppliers and customers was adopted by most of the firms (15%), which is not surprising because in a fast-changing market, such as textile products, collaboration with customers throughout the product development phase is essential for meeting specific customer needs and enables firms to identify new product opportunities (Kaufmann & Kroszner, 2002). Cooperation with research institutes was the least common alliance type among the Chinese textile firms (4%). In contrast, textile firms in advanced economies frequently collaborate with research institutes (PRLog, 2009). This difference could be attributed to the facts that (a) research institutes in developed economies are more established and accumulate more knowledge and expertise as well as marketing and consulting practices (Chiesa & Tecilla, 2000) and (b) collaboration between Chinese firms and domestic research institutes is relatively new and not well formed yet (Bin, 2008).

Determinants of R&D Intensity

Logistic regression was selected for hypothesis testing in this research because it is the most suitable for categorical dependent variables and two or more categorical or continuous independent variables (Miller, Schofield-Tomschin, & Kim, 1998). Logistic regression provides a powerful tool in predicting likelihood or probability of dichotomous outcomes of a dependent variable (e.g., high/low R&D intensity) with relatively high accuracy due to low requirements of restrictive assumptions (Liou, 2008). Furthermore, logistic regression analysis gives insight into which independent variable has the highest predictable power, that is, variables with higher coefficients are more effective in predicting dichotomous outcomes. For example, for the dependent variable of R&D effectiveness, all the three coefficients of the independent variables were interpreted regarding their contribution to the likelihood of firm profit margin increase (Liou, 2008).

The first binary logistic regression model examined which independent variables (involvement in international operations, foreign ownership, and financial resources) were significant predictors of R&D intensity. The binary logistic model (log likelihood = 21.82, $\chi 2 = 10.60$, $p < .05$) adequately fits the data. Involvement in international operations was a significant predictor of R&D intensity ($\beta = .86$ $\chi 2 = 8.63$, $p < .001$), supporting Hypothesis 1. Chinese textile firms with international operations were more likely to have high R&D investment levels than firms without international operations. Coefficient Exp (β) for the variable was 2.18 (Table 1), which indicated that Chinese textile firms involved in international operations were 2.18 times more likely to have high R&D intensity than firms that did not have any international operations.

As shown in Table 1, foreign ownership was not a significant predictor of R&D intensity ($\beta = .10$, $\chi 2 = 0.02$, $p = .897$). Hypothesis 2 was not supported. This result indicated that Chinese textile firms with foreign ownership did not have a significantly greater level of R&D investment than firms without foreign ownership.

A firm's financial resources was not a significant predictor of R&D intensity ($\beta = .54$, $\chi 2 = 1.57$, $p = .55$). Hypothesis 3 was not supported. This result implies that Chinese textile firms with greater financial resources had the same likelihood of having high R&D investment level, or high R&D intensity, as firms with lower financial resources.

Table 1. Binary Logistic Regression Parameter Estimates for R&D Intensity

Independent Variables	β	SD	Wald	Exp (β)
Involvement of foreign ownership	.45	.67	.45	1.57
Involvement in international operations	.80**	.29	7.15	2.18
Fire financial resources	.54	.43	1.57	1.71

Note. The reference category is low R&D intensity.
**p < .01.

Determinants of R&D Effectiveness

To test Hypotheses 4–6, binary logistic regression was used to examine contributions of the three independent variables (R&D intensity, type of external R&D, and internal R&D) to the likelihood of Chinese textile firms' R&D effectiveness. The model (log likelihood = 47.99, $\chi 2$ = 18.17, $p < .001$) gave significantly improved predictions compared to the Null model, indicating that the model adequately fit the data. The parameter estimates for the binary logistic model for R&D effectiveness are presented in Table 2.

The results showed that R&D intensity did not have a significant contribution to R&D effectiveness ($\beta = .40$, $x^2 = 3.77$, $p = .054$). Hypothesis 4 was not supported. The result indicated that higher investment in R&D was not necessarily associated with R&D effectiveness, meaning that investing a higher percentage of total sales in R&D did not necessarily translate into positive profit margins for Chinese textile firms.

The results showed that type of external R&D (acquisition) was a significant predictor of R&D effectiveness ($\beta = .44$, $\chi 2 = 6.00$, $p < .05$). Hypothesis 5 was supported. Chinese textile firms that invested in acquiring technology and/or equipment were more likely to have positive profit margins. Coefficient Exp (β) for acquisition was 1.56 (Table 2), which indicates that the Chinese textile firms that invested in acquisition (i.e., purchasing and licensing) type of external R&D were 1.56 times more likely to have positive profit margins in comparison with firms using imitation type of external R&D.

Internal R&D was also a significant predictor of R&D effectiveness ($\beta = .56$, $\chi 2 = 9.77$, $p < .001$). Hypothesis 6 was supported. The finding indicated that Chinese textile firms engaging in internal R&D were more likely to have positive profit margins (higher R&D effectiveness) than those relying only on external type of R&D. Coefficient Exp (β) for internal R&D was 1.74 (Table 2), indicating that Chinese textile firms that invested in internal R&D were 1.74 times more likely to have positive profit margins as compared to firms that did not invest in internal R&D.

Table 2. Binary Logistic Regression Parameter Estimates for R&D Effectiveness

Independent Variables	β	SD	Wald	Exp (β)
Acquisition/imitation technology	.44*	.18	6.00	1.56
Internal R&D	.56**	.18	9.77	1.74
R&D intensity	.40	.21	3.77	1.50

Note. The reference category is no profit margin increase.
*p < .5. **p < .01.

Discussion and Conclusions

Given the Chinese textile industry's diminishing comparative advantage associated with low labor and production costs, R&D is predicted to become a new strategic direction for the industry to remain competitive in the global marketplace (Yang et al., 2010). As a relatively new phenomenon, very little is known about Chinese textile firms' R&D processes, intensity, and effectiveness. This research provides insights into these matters by offering a comprehensive investigation of R&D activities among textile firms in a southeastern county in China.

The findings may indicate that, overall, R&D investment levels among Chinese textile firms are relatively low, for example, 64% of the surveyed firms invested less than 2.0% of their total sales on R&D. A majority (96%) of the firms were involved in some kind of external R&D activities, among which purchasing machinery and technology was the most common (46%), followed by imitation of products and processes (23%). In comparison to the external R&D adoption rate, fewer textile firms (75%) utilized internal R&D. The most common R&D alliance mode adopted by Chinese textile firms was cooperation with partners/suppliers (15%). The least common alliance mode was cooperation with research institutes (4%). By comparison, textile firms in developed countries frequently collaborate with research institutes for R&D activities (PRLog, 2009).

The results suggest that current R&D activities in the Chinese textile industry are still substantially behind those in advanced textile industries. First, Chinese textile firms surveyed in this study reported a lower R&D investment level (64% of firms invested less than 2.0% of total sales) than is observed in advanced textile industries, which is typically between 2.0% and 5.0% (European Commission, 2008). Yet, Chinese textile firms exhibited a relatively high satisfaction with their current technology level (i.e., 96% of the firms in the survey considered their current technology levels to be at or above the industry's average level). This might indicate that textile firms in China still regard R&D as a not very important competitive strategy. Second, firms in advanced textile industries tend to adopt more sophisticated R&D types in comparison to firms in the Chinese textile industry. This was demonstrated by the Chinese textile firms' (a) higher reliance on external rather than internal R&D and (b) lower involvement in R&D alliances with research institutes.

Beyond describing the current R&D status in the Chinese textile industry, the authors used RB theory to examine three predictors—involvement in international operations, foreign ownership, and financial resources—that might impact Chinese textile firms' R&D intensity. The results showed that only involvement in international operations was a significant predictor of R&D intensity among Chinese textile firms. Conversely, Chinese textile firms with foreign

ownership tend to have the same level of R&D investment in comparison to domestically owned Chinese firms. A possible explanation for these results could be recent initiatives undertaken by the Chinese government to stimulate high-tech processes and innovation in manufacturing industries, including the textile sector (Linton, 2008). It is likely that governmental support has been successful in reducing the gap between R&D intensity among textile firms with Chinese versus foreign ownership. Another explanation could be that Chinese textile firms with foreign investment were likely to have free access to innovative products and processes developed by foreign partners and, therefore, had no need for additional expenditure in R&D (Kumar & Saqib, 1996).

Relationship between firms' financial resources and level of R&D intensity has been a controversial issue in the research stream, with scholars arguing for and against the relationship (Cohen et al., 1987). Our results were in line with several studies that empirically demonstrated that a firm's financial resources were not a significant predictor of the firm's R&D investment level (Lee & Sung, 2005). This could be due to the fact that financial resources' impact on R&D investment (a) depends on a firm's technological competence in absorbing large R&D investment (Lee & Sung, 2005) and (b) is contingent on the industry, that is, levels of R&D investment returns differ across industries (Cohen et al., 1987). It is possible that despite the availability of financial resources, Chinese textile firms might be reluctant to invest in R&D due to concerns about low investment return.

We investigated three predictors of R&D effectiveness, operationalized as firm profit margin. This study provided empirical evidence that type of external R&D (imitation or acquisition) and investment in internal R&D were significant predictors of Chinese textile firms' R&D effectiveness. Chinese textile firms that relied on acquiring new machinery/technology were more likely to report positive profit margins than firms that relied on imitation of new products and processes. Further, Chinese textile firms that were involved in internal R&D activities were more likely to achieve positive profit margin than firms that were involved only in external R&D.

It was found that R&D intensity was not a significant predictor of R&D effectiveness or of a firm's positive profit margin. There are several possible explanations for this result. First, R&D is a costly activity that has a direct negative impact on a company's balance sheet, and an indefinite level of R&D investment does not necessarily yield proportional financial rewards (Yeh et al., 2010). A significant investment in new machinery or technology might have an effect on firms' profits in a year or two after the investment. Further, Lee et al. (1996) state that R&D can only be effective if it is integrated into all company operations, for example, ensuring sufficient support from nonmanufacturing functions of a firm such as marketing and sales. The result implies that greater R&D spending does not necessarily translate into positive profit margins among Chinese textile firms. This finding stresses the importance of Chinese textile firms to identify an optimal R&D expenditure level at which they can best balance R&D expenditures and returns from R&D investments.

This study provides a timely report on current R&D activities among Chinese textile firms and determines factors influencing R&D intensity and R&D effectiveness in the world's leading textile industry. The research findings may assist both policy makers and industry practitioners in allocating resources to optimize R&D investments in the Chinese textile industry. For the private sector, when implementing R&D with the goal of a higher firm performance, Chinese textile firms should (a) invest more in technology and machinery acquisition rather than relying on imitation of innovative products and processes; (b) engage in internal R&D activities

to ensure sufficient absorptive capability, which is critical for successful implementation of external R&D; and (c) actively participate in international operations, increasing the exposure to advanced products and processes, knowledge, and technology. However, individual Chinese textile firms should be prudent in increasing R&D investment, given that higher R&D intensity does not necessarily result in a greater profit margin. Instead, when considering increasing R&D investment, a Chinese textile firm should (a) ensure that R&D activities are supported by all departments and functions within the organization and (b) evaluate the effect of potential input (direct deduction on balance sheet) against output (potential financial gains) of the planned R&D activities.

Given the importance of R&D for upgrading the industry and the current relatively low R&D investment level in the Chinese textile industry, the industry leadership should promote greater interest in R&D activities. For example, governmental organizations can develop a policy to financially stimulate Chinese textile firms' involvement in internal R&D. In addition, because firms' investment in R&D depends on their participation in international operations, government policies can be directed toward encouraging greater corporate engagement in foreign activities. However, caution should be exercised when generalizing the findings of this research to a national level, as the sample in this study was drawn from textile manufacturers located in a county that has a well-developed textile industry in comparison with the rest of China. For example, R&D investment at the national level could be even lower than that described in this study (i.e., the majority of firms invested less than 2.0% of annual sales), whereas the percentage of firms utilizing imitation as the primary external R&D channel might be higher at the national level than the 23% reported in this study. Unverified relationships between foreign ownership and R&D intensity and firm financial resources and R&D intensity deserve further examination. Future studies should also focus on investigating aspects of Chinese textile firms' R&D that were not covered in this study. Other factors that might influence Chinese textile firms' R&D effectiveness and R&D intensity, such as institutional factors, also deserve further investigation.

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Notes

1. In Chinese and in the survey, it is expressed as "zhu ce zi jin" (注册资金).

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