Internationalization and Technology Strategies: Evidence from Chinese Firms

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Abstract

Different forms of internationalization lead firms to use different technology strategies. We use a sample of Chinese firms to detect systematic relations between forms of internationalization and choices of technology strategies. We consider four forms of internationalization: ordinary exports, processing exports, majority FDI, and minority FDI. We examine decisions with regard to process versus product innovations, internal versus external technology development, and foreign versus domestic technology sourcing. We find that both exporting and FDI stimulate process innovation. Ordinary exports, processing exports and FDI have strong, weak and no effects on stimulating product innovation, respectively. Exporting firms source technologies both internally through R&D and externally from foreign and domestic sources. FDI firms have a lower tendency of internal technology development and domestic technology sourcing but a much higher tendency of foreign technology sourcing than exporting firms.

Key Words

Exporting, FDI, Technology Adoption, Technology Sourcing, Chinese Firms

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Introduction

Many studies have shown that firms may benefit technologically from internationalization. For firms engaging in exporting activities, it is argued that participation in export markets brings firms into contact with international best practice (World Bank 1997) and facilitates their learning from international experience (Burpitt/Rondinelli 2000); buyers of exports may offer technical assistance to improve exporting firms' technology (Evenson/Westphal 1995) and suggest ways to improve their manufacturing process (Grossman/Helpman 1991). For firms engaging in FDI, it is found that MNEs facilitate technology transfers (Dunning 1993, chapter 11) and indigenous firms benefit from international technology spillovers (Tian 2007).

Despite the existence of a large literature on technological benefits from internationalization, there is relatively little research that maps technology strategies of firms to modes of internationalization. Witt (1998) develops a classification of technology strategies. He distinguishes between strategies of process innovation with no product changes (Strategy 1), product innovation with no process changes (Strategy 2), and a combination of process and product innovation (Strategy 3); he also distinguishes between strategies of internal and external development of technologies. In a study of technology strategies adopted by joint ventures between western MNEs and Korean companies, Pak/Park (2004) find that a favorable relation between partners of joint ventures enhances the technology transfer of new product development but not manufacturing process skills. While the existing studies provide useful discussions on classification of technology strategies (Witt 1998) and on choices of technology strategies by firms engaging in certain type of internationalization (Pak/Park 2004), they have not explored systematic relations between technology strategies and different types of internationalization. This paper aims to fill this gap. We first develop theoretical hypotheses that link different technology strategies with different forms of internationalization, and then test the hypotheses using data of Chinese firms.

Theories and Hypotheses

Technology Strategies

Technological innovations are defined as the introduction of a new product or a new production process. According to Witt (1998), pure process innovation (with no changes in products) leads to reduced product cost, while pure product innovation (with no changes in production processes) leads to enhanced customer value at constant costs. Pak/Park (2004) argue that new product development is expected to have more tacit and specific knowledge attributes than process skills and techniques. In this paper, we consider technology choices of process innovation versus product innovation as the first dimension in the firm's formulation of technology strategies.

Apart from the distinction between processes and products, it is also useful to draw a distinction between internal and external innovations (Witt 1998). A strategy of internal innovation is to invent and develop technologies within the firm. A strategy of external innovation refers to sourcing technologies from external channels. Nicholls-Nixon/Woo (2003) argue the need for a dual technology sourcing approach whereby firms utilize both internal and external R&D as a mean of developing new technical output. Using data from the U.S. pharmaceutical industry, they find that different strategies of technology sourcing (internal R&D and external R&D) are related to different types of biotechnology-based output. Papanastassiou/Pearce (1997), in their study of technology sourcing strategies of MNE subsidiaries in the U.K., find the need of MNE subsidiaries to extend their use of local technological expertise and widen their technological scope in response to global competition. In his discussion of technology strategies of Eastern European firms, Witt (1998) analyzes a wide range of technology sourcing choices including internal R&D, licensing, information networks, joint ventures, and acquisition. In this paper, we consider technology sourcing choices as the second dimension in the firm's formulation of technology strategies.

Forms of Internationalization

Internationalization is the process of adapting firms' operations to international environment. There are different forms of internationalization, from exporting to foreign production (Johanson/Valhne 1977, Luostarinen 1980). In the received wisdom on internationalization, knowledge is at the core (Prashantham 2005). This paper intends to contribute to the literature by examining technology strategies of firms who pursue different forms of internationalization.

We consider four forms of internationalization. The first two forms are related to international trade: ordinary exporting and processing exporting. One new development in the recent wave of globalization is international production fragmentation (Krugman 1995). As a consequence, international trade of intermediate goods has increased rapidly and many firms engage in processing exporting---exporting final goods assembled from imported parts and components (Feenstra 1998). In China, processing exports account for

55 percent of total exports to the world and 65 percent of exports to the U.S. in 2006 (Wang/Wei 2007). In the literature, however, little research attention has been paid to technology strategies of firms engaging in process exporting.

Another two forms of internationalization are related to FDI: majority FDI and minority FDI. MNEs have ownership advantages in technology. By forming joint ventures with MNEs, domestic firms may benefit technologically (Gorg/Strobl 2001). While there are many studies that examine the technology spillover effects of FDI on domestic firms (Blomstrom/Sjoholm 1999, Buckley et al. 2002), they seldom distinguish between different types of technologies (process versus product technologies) and different sourcing strategies (internal versus external innovations). This is one area in which this paper intends to make a contribution.

Theoretical Hypotheses

We now establish theoretical hypotheses that link different technology strategies with different forms of internationalization. First consider exporting firms' choice between process innovation and product innovation. For ordinary exports, we expect exporting firms to adopt both higher levels of process technology and higher levels of product technology. The literature features two effects of ordinary exports. First, firms with higher productivity select to be exporters (Bernard/Jensen 1999, Melitz 2003). Second, exposure to international markets facilitates learning and technology absorption (Zahra et al. 2000). While the causality between exporting and productivity is debatable (Clerides, et al. 1998), both theory and empirical evidence suggest that exporting firms will exhibit higher levels of process and product technology than domestic market oriented firms. As Witt (1998) argues, exporting firms need to employ higher levels of process technology to build its productivity advantage, and higher levels of product technology to make their products meet the preferences of foreign customers. In comparison, processing export firms compete for export orders to assemble final goods from intermediate inputs, and hence they must improve their process technologies. However, processing export firms usually do not export directly to international markets; most often they are simply produce according the requirements of importing companies. Thus, we expect that processing export firms are relatively weak in product innovation. The above discussion leads to the following hypothesis.

Hypothesis 1: Firms of ordinary exports will tend to be more active in both process and product innovations than firms serving the domestic market. Firms of processing exports will tend to be more active in process innovation but not in product innovation.

In many countries including China, processing exports are largely done in export processing zones (Blanco de Armas/Sadni-Jallab 2002). Export processing zones (EPZs) are enclaves in which goods may be imported, stored, repacked, manufactured, and reshipped with a reduction in duties (Madani 1999). Some percent of the EPZ production may be sold on the domestic market after appropriate import tariffs on the final goods are paid. Thus, there are both exporting firms and non-exporting firms in EPZs. Because the non-exporting firms in EPZs aim to sell in the domestic market, their technology strategies should differ from the exporting firms. While EPZ exporting firms produce according to export orders and hence have less a tendency to adopt product innovation, non-exporting firms in EPZs may benefit from product technology spillovers generated by exporting firms since products for the world market exhibit features that are new to the domestic market. On the other hand, to serve the domestic market, non-exporting firms in EPZs do not need to adopt processing technologies at the same high level of exporting firms in EPZs. We establish the following hypothesis.

Hypothesis 2: In export processing zones, exporting firms have a higher tendency of adopting process innovation than non-exporting firms, but a lower tendency of adopting product innovation than non-exporting firms.

Next we turn to technology strategies of FDI firms. In their study of knowledge transfer in international joint ventures, Pak/Park (2004) develop a hypothesis based on conflict between joint venture partners: the higher the degree of conflict between the joint venture partners, the less knowledge will be transferred to the local partner. Applying this reasoning, we hypothesize that the higher the control of MNEs (measured by FDI share in ownership), the higher the tendency of adopting technology innovations. Pak/Park (2004) argue further that the more tacit the knowledge of MNEs, the less knowledge will be transferred to joint venture partners. Since product innovation is considered to involve more tacit and specific knowledge attributes than process innovation, we hypothesize that FDI firms have a relatively low tendency to adopt product innovation as compared to process innovation. We summarize the above arguments in the following hypothesis.

Hypothesis 3: FDI joint ventures tend to have a strong tendency of adopting process innovation but a relatively weak tendency of adopting product innovation. The higher the degree of FDI involvement, the higher is the degree of process innovation.

We now turn to strategies of technology sourcing. Firms may source technologies internally (doing R&D) and externally from domestic sources and foreign sources (purchasing technology licenses, importing machinery and equipment, etc.). According to some studies (Bernard/Jensen 1999, Melitz 2003), exporting firms are self-selected to be the more productive ones. This implies that within the same industry, exporting firms are likely to be more intensive in R&D. Some other studies (Grossman/Helpman 1991, Burpitt/Rondinelli 2000, Zahra et al. 2000) find that exporting stimulates learning, imitation, and innovation. This implies that exporting firms are likely to benefit more from foreign sources of R&D than firms serving the domestic market. Based on the above arguments, we establish the following hypothesis.

Hypothesis 4: Exporting firms will tend to be more active in both internal development and external sourcing of technologies, and rely more on foreign sources of technologies than firms serving the domestic market.

FDI joint ventures are a conduit of technology transfer (Hejazi/Safarian 1999). In developing countries such as China, FDI joint ventures involve mainly MNEs from industrialized countries.[1] According the OLI paradigm (Dunning 1993), foreign partners in joint ventures possess ownership advantages that include technology and information. Because of these ownership advantages, FDI firms are expected to rely mainly on foreign sources of technologies. Nicholls-Nixon/Woo (2003) argue that the greater the number of different types of technology sourcing linkages (R&D contacts, licenses, acquisitions, joint ventures and minority equity ownership) pursued by the firm, the greater the subsequent technical output of the firm. FDI firms have access to more channels of technology sourcing than non-FDI firms and thereby are expected to possess higher technology capability. On the other hand, although FDI firms are generally more intensive technologically than non-FDI firms, they may spend less R&D for internal development of technologies because of their advantages in external sourcing of technologies. Based on the above discussion, we establish the following hypothesis.

Hypothesis 5: FDI firms will tend to be less active in internal development and more active in external sourcing of technologies than non-FDI firms including exporting firms. The higher the involvement of FDI, the higher will be the degree of foreign technology sourcing, and the lower will be the degree of domestic technology sourcing.

Data and Methods

Sample

Our data comes from a World Bank survey of 1500 firms in China.[2] The survey randomly draws 300 firms each from five major cities, Beijing, Chengdu, Guangzhou, Shanghai, and Tianjin. We focus on the 998 firms in manufacturing sectors and exclude the other 502 firms in service sectors. For our study of internationalization of domestic firms, we exclude the 111 wholly foreign owned subsidiaries. To avoid a potential statistical bias of including firms of very small size, we drop 16 firms with number of employees below 10.[3] The resulting sample contains 871 manufacturing firms, which are distributed in five industries: Apparel and Leather Goods (195), Electronic Components

(163), Electronic Equipment (171), Consumer Products (142), and Vehicles and Vehicle Parts (200). The sample period is 1998-2000 (fiscal years).

Dependent Variables

We use seven dependent variables to capture different aspects of the firm's technology strategies. Table 1 reports their descriptions and summary statistics.

[Table 1 about here]

In our study, AUTO is a measure of process innovation and NEWP is a measure of product innovation. AUTO is share in net value of fixed assets of computer controlled production machines in use, which measures intensity of adopting automatic process technology. Values of AUTO are in 2000. For the 833 firms having this data, mean value of AUTO is 0.212. NEWP is a dummy variable for new product introduction. NEWP equals one if the firm introduced new products in the sample period, and zero otherwise. Sample mean of NEWP is 0.501.

We use RDY as a measure of internal technology development. RDY is R&D intensity in 2000, measured by ratio of R&D expenditure to total sales. For the 840 firms having this data, mean value of RDY is 0.029. We use two variables, MACH and FLIC, as measures of foreign sourcing of technologies. MACH is a dummy variable of importing machinery and equipment. MACH equals one if the firm imported machinery and equipment in the sample period, and zero otherwise. Sample mean of MACH is 0.38. FLIC is the number of licenses purchased from foreign firms. For the 839 firms having this data, mean value of FLIC is 0.194.

We use two variables, DLIC and DRDR, as measures of domestic sourcing of technologies. DLIC is the number of licenses purchased from domestic firms. For the 828 firms having this data, mean value of DLIC is 0.851. DRDR is a dummy variable of having a contractual or long-standing relationship with local university, government research institution, private research institution, or private companies. DRDR equals one if the firm has such a relationship, and zero otherwise. Sample mean of DRDR is 0.201.

Independent Variables

Our hypotheses are concerned with the impact of internationalization on the firm's choices of technology strategies. We use six variables to capture different forms of internationalization. Table 1 reports their descriptions and summary statistics.

Three variables are related to exporting or export processing zones. First, EXP is a dummy variable for exporting firms not located in EPZs. Exporting firms are defined as the ones that exported in 1998 or 1999. EXP equals one if the firm was not located in EPZs and exported in 1998 or 1999, and zero otherwise. Sample mean of EXP is 0.254. Second, EPZE is a dummy variable for exporting firms located in EPZs. EPZE equals one if the firm was located in EPZs and exported in 1998 or 1999, and zero otherwise. Sample mean of EPZE is 0.116. Third, EPZN is a dummy variable for non-exporting firms located in EPZs. EPZN equals one if the firm was located in EPZs but did not export in 1998 and 1999. Sample mean of EPZN is 0.119.

Another three variables are related to FDI. First, FMAJ is a dummy variable for firms with majority foreign ownership. FMAJ equals one if share of foreign ownership is greater than or equal to 0.5 but less than 1, and zero otherwise. Sample mean of FMAJ is 0.208. Second, FMIN is a dummy variable for firms with minority foreign ownership. FMIN equals one if share of foreign ownership is greater than zero and less than 0.5, and zero otherwise. Sample mean of FMIN is 0.126. Third, FOR is share of foreign ownership in the survey year of 2001. This variable is used as a continuous measure of FDI involvement. For the 793 firms having this data, mean value of FOR is 0.14.

Control Variables

To estimate the effects of the internationalization variables on the firm's choices of technology strategies, we include the following control variables.

First, lagged R&D intensity (RDYL), measured by ratio of R&D expenditure to total sales averaged over 1998 and 1999.[4] Technological innovations in both products and processes depend on the absorptive capability of the firm (Cohen/Levinthal 1990). For the 758 firms having data on RDYL, mean value equals 0.074, that is, R&D expenditure is 7.4 percent of total sales.

Second, lagged firm size (SIZEL), measured by total sales (in 1998 value) averaged over 1998 and 1999. Studies find that firm size plays an important role in the firm's technology decisions (Cohen/Klepper 1996, Yin/Zuscovitch 1998). For the 779 firms having data on SIZEL, mean value is 0.185 (million yuan).

Third, share of government ownership (GOV). In China, government-owned firms are found to have a lower tendency in technology innovation (Tan 2001). For the 869 firms having data on GOV, mean value is 0.226.

Fourth, industry dummies to capture unobserved industry effects. In ascending order of average RDYL, the five industries are Apparel and Leather Goods (0.005), Consumer Products (0.026), Electronic Equipment (0.032), Electronic Components (0.038), and Vehicles and Vehicle Parts (0.231). We use the least R&D-intensive industry, Apparel and Leather Goods, as the base industry in our regressions.

Fifth, city dummies to capture unobserved city effects. In ascending order of average export intensity (ratio of export sales to total sales averaged over 1998 and 1999), the five cities are Chengdu (0.05), Beijing (0.11), Tianjin (0.16), Shanghai (0.23), and Guangzhou (0.38). In ascending order of average foreign ownership share (FOR), the five cities are Chengdu (0.05), Beijing (0.12), Tianjin (0.13), Guangzhou (0.21), and Shanghai (0.26). Notice that Chengdu, a city in inner China, is least open in both exporting and FDI. We use Chengdu as the base city in our regressions.

Regression Methods

Based on the discussions on theoretical hypotheses, we specify the following regression model.

$$Y = \beta_I + \beta_C + \beta_1 EXP + \beta_2 EPZE + \beta_3 EPZN + \beta_4 FOR/(FMAJ\&FMIN)$$
$$+ \beta_5 GOV + \beta_6 RDYL + \beta_7 SIZEL + \varepsilon. \qquad (1)$$

In equation (1), Y is one of the dependent variables (AUTO, NEWT, RDY, MACH, FLIC, DLIC, DRDR), β_I denotes industry dummies, β_C denotes city dummies, and ε is an error term. The right-hand side variables include independent variables of internationalization (EXP, EPXE, EPZN, FOR, FMAJ, FMIN) and control variables (GOV, RDYL, SIZEL). To capture a firm's internationalization in terms of FDI, we use either foreign ownership share (FOR) or dummies of majority foreign ownership (FMAJ) and minority foreign ownership (FMIN). Table 2 reports the correlation matrix of the right-hand side variables. We find that the correlations between most variables are rather small. The relatively high correlations are those between export and FDI variables, which are about 10 to 30 percent. Thus, there is not a serious concern about multicollinearity.

[Table 2 about here]

We use either OLS or LOGIT regressions in our study. For continuous dependent variables (AUTO, RDY, FLIC, DLIC), we use OLS regression method. For discrete dependent variables (NEWT, MACH, DRDR), we use LOGIT regression method. In all regressions heteroskedesticity is adjusted to obtain robust standard errors.

Empirical Results

Technology Adoption

Table 3 reports regression results on Chinese firms' adoption of automatic process technologies (AUTO) and introduction of new products (NEWP). We find that Non-EPZ exporting firms (EXP), which conduct mainly non-processing export businesses, are significantly higher in both AUTO and NEWP than firms with no internationalization (base firm group of the regressions). We find that EPZ exporting firms (EPZE), which conduct mainly processing export businesses, have higher AUTO than Non-EPZ exporting firms, but lower NEWP than Non-EPZ exporting firms. Recall Hypothesis 1 which states that firms of ordinary exports will tend to be more active in both process and product innovations than firms serving the domestic market, while firms of processing exports will tend to be more active in process innovation but not in product innovation. Our results largely support this hypothesis; the only deviation is that the effect of EPZE on NEWP is hypothesized to be zero but is found positive with marginal statistical significance. The hypothesis postulates that processing exporting firms have no incentive to introduce new products because they produce according to export orders. Our finding indicates that although product innovation incentive of processing exporting firms is weak, it is still higher than that of firms with no internationalization.

[Table 3 about here]

Next we compare exporting firms in EPZs (EPZE) and non-exporting firms in EPZs (EPZN). In regressions (3) and (4), we find that the estimated coefficients on EPZN are positive and statistically significant at the 1 percent level, while the estimated coefficients on EPZE are small and only marginally significant. This finding confirms our conjecture that non-exporting firms located in EPZs benefit from product technology spillovers generated by exporting firms since products for the world market exhibit features that are new to the domestic market. On the other hand, we find from regressions (1) and (2) that the estimated coefficients on EPZN are significantly lower than the estimated coefficients on EPZE. This finding indicates that non-exporting firms do not need to adopt process technologies (AUTO) at the same high level of exporting firms. Taking together these results support Hypothesis 2.

Turning to FDI variables (FMAJ, FMIN, FOR), we find that they are positive and statistically significant in regressions (1) and (2), but statistically insignificant in regressions (3) and (4). In the first two regressions, the dependent variable is AUTO. Regression (1) indicates that majority foreign-owned firms (FMAJ) are higher by 10.8 percent in intensity of adopting computer-controlled production processes (AUTO) than the benchmark group of firms with no internationalization, and minority foreign-owned firms are higher by 5.8 percent. In Regression (2) we use foreign ownership share (FOR) as the independent variable and find that AUTO rises with FOR. In sharp contrast, we find from regressions (3) and (4) that FDI involvement does not have any significant effect on new product introduction (NEWP). These results suggest that FDI firms gain their technology strength mainly from adoption of advanced production processes, and not from introduction of new products, which supports Hypothesis 3.

In all the regressions of Table 3, we include control variables of government ownership share (GOV), firm R&D intensity (RDYL), firm size (SIZEL), industry dummies, and city dummies. The estimated effects of these control variables are largely consistent with expectation. We find that AUTO declines as GOV increases, which confirms the belief that government ownership hinders firms' adoption of advanced process technologies. We find no evidence however that government ownership hinders firms' introduction of new products. As expected, we find that firms with higher R&D intensity have a higher tendency to adopt advanced process technologies and introduce new products. Yin/Zuscovitch (1998) argue that different innovation incentives cause the larger firm to invest more in process innovations and the small one to allocate more resources to search for new products; our results show that firm size matters for adoption of process technologies but not for introduction of new products. With apparel and leather as the base industry, the estimated coefficients on industry dummies are all positive and statistically significant as expected. City dummies are statistically insignificant in regressions of AUTO, which suggests that location does not impact firms' decisions on process innovation. In NEWP regressions, two city dummies (Guangzhou and Tianjin) are negative, which suggests that there are unobserved location effects in these two cities that impact firms' decisions on product innovation.

Technology Sourcing

Table 4 reports results on Chinese firms' technology sourcing from internal development (RDY), importing machinery and equipment from abroad (MACH), purchasing technology licenses from foreign firms (FLIC), purchasing technology licenses from domestic firms (DLIC), and establishing relationships with domestic R&D

institutions (DRDR). In all regressions the reference firm group is the group of firms with no internationalization.

[Table 4 about here]

We find that exporting firms (EXP, EPZE) spend more on R&D than the reference group of firms with no internationalization (regression 5), and have a higher tendency of importing machinery and equipment from abroad (regression 6). These findings support Hypothesis 4. The point estimates suggest that the degree of internal technology development through R&D is about the same for exporting firms in EPZs and outside of EPZs. In terms of foreign technology sources, EPZ exporting firms reply mainly on importing machinery and equipment from abroad (which is consistent with its focus on process innovation), while non-EPZ exporting firms have less a reliance on importing machinery but more on purchasing foreign technology licenses. From regressions (8) and (9), we find that estimated coefficients on DLIC and DRDR are statistically insignificant for non-EPZ exporting firms, while estimated coefficient on DRDR is positive and significant for EPZ exporting firms. These estimates suggest that both types of exporting firms still rely on domestic technology sources to some degree; in particular, exporting firms in EPZs have high reliance on relationships with domestic R&D institutions.

It is interesting to observe that non-exporting firms in EPZs have neither a higher tendency of machinery importing (MACH) nor a higher tendency of license purchasing (FLIC, DLIC). Adopting imported machinery is part of process innovation, so the result on MACH is consistent with our early finding that non-exporting firms in EPZs are less active in process innovation. Notice that in regression (9), EPZN has a positive estimated coefficient with regard to DRDR that is large and statistically significant. This result suggests that non-exporting firms in EPZs tend to establish close relationships with R&D institutions located in EPZs as a source of technologies.

Compared with exporting firms, FDI firms have much less reliance on internal development of technologies and on domestic sourcing of technologies. Regression (5) shows that the estimated coefficient on foreign ownership share (FOR) is negative and statistically significant.[5] The higher the share of foreign ownership, the lower is the degree of internal development of technologies through R&D. This result may seem counter-intuitive as it reveals a negative correlation between R&D intensity and foreign ownership. However, the result makes sense because it is obtained after controlling for export status (EXP, EPZE), lagged R&D intensity (RDYL) and industry R&D levels implied in industry dummies. Although FDI firms have higher R&D intensity than non-FDI firms, they tend to spend less R&D in internal development of technologies. Instead, they obtain technologies mainly from external foreign sources. As regressions (6) and (7) indicate, FDI firms have a higher tendency in both importing machinery and equipment (MACH) and purchasing foreign licenses (FLIC). Moreover, the results indicate that the higher the share of foreign ownership, the higher is the degree of foreign technology sourcing. In addition, we find from regressions (8) and (9) that the estimated coefficients on FOR are negative and statistically significant, which says that the higher the share of foreign ownership, the lower is the degree of domestic technology sourcing. Collectively the above results provide strong evidence supporting Hypothesis 5.

In all the regressions of Table 4, we include control variables of government ownership share (GOV), firm R&D intensity (RDYL), firm size (SIZEL), industry dummies, and city dummies. We expect GOV to have a negative effect on technology development and sourcing, and find that GOV is indeed negatively related to R&D spending (RDY) and foreign license purchasing (FLIC). We find, however, that GOV is positively related to importing machinery and equipment (MACH). Our interpretation is that machinery importing reflects both technology sourcing and capacity building. In China, government-owned firms can get cheap credit and thus have an incentive to build up capital capacity. We find that lagged R&D intensity (RDYL) is statistically insignificant in all regressions; this result suggests that technology sourcing behavior of Chinese firms is insensitive to their R&D levels. We find that firm size has a positive effect on internal technology development (regression 5) and purchasing of foreign licenses (regression 7), but no effect on other technology sourcing variables.

The base industry for our regressions is apparel and leather industry. It appears that China's apparel and leather firms have a higher tendency of importing machinery and equipment, so the estimated effects of industry dummies are all negative in the regression of MACH. In all other regressions, the estimated effects of industry dummies are mostly positive as expected since apparel and leather industry is the least technology-intensive industry. The base city for our regressions is Chengdu, which is the only city in our sample that is located in inner China. We find that the estimated effects of city dummies are negative and statistically significant for both DLIC and DRDR, which is evidence that firms in inner regions of China rely more on domestic technology sources than firms in costal regions of China. Interestingly we find that estimated effects of some city dummies are also negative for foreign technology source variables; this suggests that location does not necessarily impose a constraint on firms' sourcing of foreign technologies.

Conclusion

Firms with different forms of internationalization pursue different types of technology strategies. In this paper we use a sample of Chinese firms to detect systematic relations between forms of internationalization and strategies of technology adoption and sourcing. We distinguish between four forms of internationalization: processing exporting, non-processing exporting, majority FDI, and minority FDI. We examine choices of firms between process innovation and product innovation, between internal technology development and external technology development, and between foreign technology sourcing and domestic technology sourcing.

Our study yields two main results with regard to firms' strategies in technology adoption and technology sourcing. First, we find that both exporting and FDI stimulate firms to adopt more advanced process technologies; the higher the involvement of FDI, the higher is the degree of process innovation. We find that exporting also stimulates firms' introduction of new products, but we find no evidence that FDI promotes new product introduction. Between firms of ordinary exports and processing exports, we find that the former gain technology strength less from process innovation and more from product innovation, while the latter gain technology strength more from process innovation and less from product innovation.

Second, we find that firms with different forms of internationalization pursue different strategies of technology sourcing. Exporting firms source technologies both internally through R&D, and externally from domestic and foreign sources. In terms of foreign technologies, firms of ordinary exports tend to obtain them from importing machinery and from purchasing foreign technology licenses, while firms of processing exports tend to rely on machinery importing but not license purchasing. Compared with exporting firms, FDI firms have a much lower tendency of internal technology development and domestic technology sourcing but have a much higher tendency of foreign technology sourcing. The higher the involvement of FDI, the higher is the degree of foreign technology sourcing from machinery importing and foreign license purchasing, the lower is the spending of R&D on internal technology development, and the lower is the degree of domestic technology sourcing from domestic license purchasing and relationships with local research institutions.

Limited by data, we are not able to explore more deeply into the impacts of internationalization on Chinese firms' technology decisions. For example, our data does not allow us to distinguish between FDI sources. Several studies (Buckley et al. 2002, Wei/Liu 2006) find that firms with FDI from Hong Kong, Macao and Taiwan behave very differently from firms with FDI from OECD countries. An investigation of these two types of FDI firms will shed light on the roles played by culture proximity and Guanxi (relationships) in technology decisions. While our data distinguishes EPZ exporting firms from non-EPZ exporting firms, it does not distinguish between processing and non-processing export firms; some exporting firms outside EPZs are processing export firms. A study with data on processing export firms will provide more reliable evidence on technology strategies chosen by these firms. Last but not least, while we identify machinery imports, license purchasing, and R&D relationships as alternative channels of technology sourcing, there are other important channels that we do not examine, such as R&D alliances. Future research is needed to explore these and other issues related to internationalization and firms' choices of technology strategies.

Endnotes

1. FDI inflow from industrialized countries accounts for more than 50 percent of China's total FDI inflow in all years after 2000.
2. The data is available at the website of Davidson Data Center & Network (DDCN). We thank the World Bank and DDCN for providing the data.
3. Our results are not sensitive to the exclusion of these 16 small firms.
4. Values of R&D expenditure and sales are converted to 1998 values using the GDP deflator calculated from *China Statistical Yearbook*, 2001. The GDP deflator is 0.978 for 1999, with 1998 as the base year.
5. Using FMAJ and FMIN as independent variables yields essentially the same results, which we do not report to save space.

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Table 1: Variable Description and Summary Statistics

Variable	Description	Mean	Standard Deviation	Observations
AUTO	Share in net value of fixed assets of computer controlled production machines in use	0.212	0.294	833
NEWP	New product introduction dummy	0.501	0.500	871
RDY	R&D intensity in 2000	0.029	0.098	840
MACH	Machinery import dummy	0.380	0.486	871
FLIC	Number of licenses purchased from foreign firms	0.194	1.101	839
DLIC	Number of licenses purchased from domestic firms	0.851	3.370	828
DRDR	Relationship with domestic R&D institutes, dummy	0.201	0.401	871
EXP	Non-EPZ exporting dummy	0.254	0.435	871
EPZE	EPZ exporting dummy	0.116	0.320	871
EPZN	EPZ non-exporting dummy	0.119	0.324	871
FMAJ	Majority foreign-owned dummy	0.208	0.406	871
FMIN	Minority foreign-owned dummy	0.126	0.332	871
FOR	Share of foreign ownership	0.140	0.257	793
GOV	Share of government ownership	0.226	0.393	869
RDYL	R&D intensity averaged over 1998-1999	0.074	0.980	758
SIZEL	Firm size (sales) averaged over 1998-1999	0.185	1.231	779

Note: EPZ refers to export processing zone.

Table 2: Correlation Matrix

	1	2	3	4	5	6	7
1. EXP	1.000						
2. EPZE	-0.211	1.000					
3. EPZN	-0.215	-0.133	1.000				
4. FOR	0.163	0.343	-0.045	1.000			
5. GOV	-0.002	-0.063	-0.005	-0.229	1.000		
6. RDYL	-0.030	0.074	-0.012	0.065	-0.005	1.000	
7. SIZEL	0.032	0.122	-0.020	0.110	-0.050	-0.001	1.000

Table 3: Regression Results on Technology Adoption

	(1)	(2)	(3)	(4)
Regression Method	OLS	OLS	LOGIT	LOGIT
Dependent Variable	AUTO	AUTO	NEWP	NEWP
EXP	0.079	0.081	0.622	0.774
	(2.85)***	(2.90)***	(2.56)**	(3.05)***
EPZE	0.164	0.143	0.496	0.592
	(4.02)***	(3.38)***	(1.57)	(1.76)*
EPZN	0.120	0.106	1.055	1.129
	(3.44)***	(3.06)***	(3.57)***	(3.78)***
FMAJ	0.108		0.073	
	(3.08)***		(0.29)	
FMIN	0.058		0.300	
	(1.64)*		(1.12)	
FOR		0.157		-0.168
		(3.03)***		(0.44)
GOV	-0.040	-0.038	0.015	0.026
	(1.77)*	(1.69)*	(0.07)	(0.13)
RDYL	0.027	0.026	5.597	5.398
	(5.75)***	(6.45)***	(1.81)*	(1.74)*
SIZEL	0.016	0.015	1.294	1.417
	(2.72)***	(3.23)***	(1.01)	(1.01)
Electronic Components	0.164	0.174	1.556	1.555
	(4.93)***	(5.15)***	(5.33)***	(5.17)***
Electronic Equipment	0.182	0.164	1.271	1.287
	(5.67)***	(5.06)***	(5.01)***	(4.87)***
Consumer Products	0.077	0.078	1.104	1.200
	(2.48)**	(2.48)**	(4.07)***	(4.23)***
Vehicles and Vehicle Parts	0.077	0.056	1.175	1.158
	(3.10)***	(2.24)**	(4.48)***	(4.21)***
Beijing	-0.014	-0.015	-0.240	-0.207
	(0.54)	(0.56)	(1.01)	(0.86)
Guangzhou	-0.018	-0.018	-0.800	-0.793
	(0.51)	(0.50)	(2.90)***	(2.82)***
Shanghai	0.027	0.017	0.067	-0.128
	(0.80)	(0.49)	(0.24)	(0.44)
Tianjin	-0.004	-0.006	-0.778	-0.789
	(0.14)	(0.19)	(2.85)***	(2.86)***
Constant	0.042	0.053	-1.260	-1.290
	(1.53)	(1.93)*	(4.57)***	(4.57)***
Observations	726	666	756	695
R-squared	0.19	0.18		
Pseudo R-squared			0.15	0.14

Notes: Base industry is apparel and leather goods. Base city is Chengdu. Robust t statistics in absolute value are in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 4: Regression Results on Technology Sourcing

	(5)	(6)	(7)	(8)	(9)
Regression Method	OLS	LOGIT	OLS	OLS	LOGIT
Dependent Variable	RDY	MACH	FLIC	DLIC	DRDR
EXP	0.031	1.119	0.280	0.262	0.336
	(2.06)**	(4.48)***	(2.71)***	(0.73)	(1.24)
EPZE	0.032	1.624	0.118	0.562	0.723
	(1.68)*	(4.68)***	(0.96)	(0.87)	(2.06)**
EPZN	0.022	0.222	0.069	-0.086	0.817
	(2.47)**	(0.80)	(0.81)	(0.28)	(2.71)***
FOR	-0.047	1.885	0.318	-0.919	-1.483
	(2.45)**	(4.55)***	(1.72)*	(1.69)*	(2.61)***
GOV	-0.013	0.493	-0.113	-0.184	-0.119
	(1.80)*	(2.26)**	(2.40)**	(0.60)	(0.49)
RDYL	0.005	1.613	0.016	0.051	-0.045
	(0.84)	(1.08)	(0.47)	(0.90)	(0.95)
SIZEL	0.004	1.390	0.088	-0.012	0.496
	(3.19)***	(1.04)	(3.42)***	(0.61)	(1.12)
Electronic Components	0.042	-0.276	0.211	0.015	1.263
	(5.64)***	(0.93)	(2.08)**	(0.04)	(3.82)***
Electronic Equipment	0.044	-0.051	0.025	-0.096	0.868
	(3.34)***	(0.19)	(0.53)	(0.29)	(2.67)***
Consumer Products	0.022	-0.837	0.345	1.172	0.439
	(3.06)***	(2.69)***	(2.14)**	(1.93)*	(1.18)
Vehicles and Vehicle Parts	0.030	-0.276	0.252	-0.135	0.454
	(3.45)***	(0.96)	(3.41)***	(0.39)	(1.35)
Beijing	-0.017	0.125	-0.098	-1.102	-0.467
	(1.63)	(0.51)	(1.49)	(2.92)***	(1.75)*
Guangzhou	-0.020	0.035	-0.216	-1.078	-0.700
	(1.39)	(0.13)	(2.20)**	(1.96)*	(2.14)**
Shanghai	-0.029	-0.229	0.267	-1.173	-0.705
	(2.69)***	(0.76)	(1.64)	(2.82)***	(1.96)**
Tianjin	-0.014	-0.932	-0.176	-1.457	-0.965
	(0.91)	(2.90)***	(2.61)***	(4.50)***	(3.04)***
Constant	0.011	-1.250	-0.044	1.728	-1.669
	(1.42)	(4.81)***	(0.61)	(4.52)***	(5.15)***
Observations	686	695	681	670	695
R-squared	0.07		0.11	0.06	
Pseudo R-squared		0.20			0.09

Notes: Base industry is apparel and leather goods. Base city is Chengdu. Robust t statistics in absolute value are in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.