THE IMPACT OF TRADE AND FOREIGN DIRECT INVESTMENT POLICIES ON TECHNOLOGY ADOPTION AND SOURCING OF CHINESE FIRMS

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How do trade and foreign direct investment (FDI) policies impact the decisions of firms in technology adoption (process vs. product innovations) and sourcing (internal vs. external and foreign vs. domestic)? We use a sample of Chinese firms to address this question. China's trade and FDI policies lead to different forms of internationalization: ordinary exports, processing exports, majority FDI, and minority FDI. 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. (*JEL* F13, F23, O32)

I. INTRODUCTION

Many studies have shown that firms may benefit technologically from international trade and foreign direct investment (FDI). For firms engaging in exports, 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 and Rondinelli 2000); buyers of exports may offer technical assistance to improve exporting firms' technology (Evenson and Westphal 1995) and suggest ways to improve their manufacturing process (Grossman and Helpman 1991). For firms engaging in FDI, it is found that multinational enterprises (MNEs) facilitate technology transfers (Dunning 1993, chapter 11) and indigenous firms benefit from international technology spillovers (Tian 2007).

The general conclusion that trade and FDI can be beneficial does not provide sufficient guide for policy makers in designing policies for different types of trade and FDI. In countries such as China and Mexico, processing trade, that is, exporting of final goods assembled from imported intermediate goods, accounts for a large amount. It is thus of particular importance to understand if and how ordinary trade and processing trade impact firms differently in the technology dimension. A recent study by Amiti and Freund (2010), for example, found evidence of significant skill upgrading in China's processing exports from 1992 to 2005, but no such upgrading in China's ordinary exports. FDI also takes different forms. According to the literature (Dunning 1993), FDI is undertaken by firms that possess specific advantages to overcome the disadvantages of doing business abroad. The tradeoff between the advantages and disadvantages leads to different FDI forms, such as wholly foreign-owned subsidiaries (WFOEs) and joint ventures (JVs). It is important for policy makers to understand if and how different forms of FDI impact firms differently

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ABBREVIATIONS

DDCN: Davidson Data Center & Network
EPZ: Export Processing Zone
FDI: Foreign Direct Investment
JVs: Joint Ventures
MNE: Multinational Enterprise
OLI: Ownership–Location–Internalization
WFOEs: Wholly Foreign-Owned Subsidiaries

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in the technology dimension. In the FDI literature, by the ownership–location–internalization (OLI) paradigm, WFOEs have the advantage of internalizing superior technology within the firm, whereas JVs rely more on the relationship with local partners to gain competitiveness in the local market. Empirical evidence (Caves 1996, section 3.4) indicates that WFOEs tend to adopt higher level technologies than JVs.

This article uses a sample of Chinese firms to explore the effects of different forms of trade and FDI on firm behavior in adopting and sourcing technology. China provides a great opportunity to investigate the effects of trade and FDI policies on technology behavior of firms. Both ordinary trade and processing trade are quantitatively significant in China, with processing trade accounting for more than half of China's total trade (Wang and Wei 2010). China has implemented various policies that help attract a large amount of FDI (Fung, Iizaka, and Tong 2004; Zhang 2001). China has also adopted active policies of export processing zones (EPZs) and technology parks. Thus, there are sufficient variations in China's trade and FDI policies that allow researchers to identify the distinctive impact of each of these policies on technology behavior of firms.

Our study views a firm's technology behavior as reflecting its technology strategy. In the literature, Witt (1998) has developed a classification of firms' technology strategies, which distinguishes between strategies of (1) process innovation with no product changes, (2) product innovation with no process changes, and (3) a combination of process and product innovation, and between strategies of internal development and external sourcing of technologies. In this article, we first develop several theoretical hypotheses that link firms' technology strategies with their trade and FDI forms, and then test the hypotheses using the data of Chinese firms. The results from our study identify several systematic relationships between forms of trade and FDI and technology strategies of firms that are useful for policy makers in their design of specific trade and FDI policies.

To preview, the article yields two main findings. 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 gains technology strength less from process innovation and more from product innovation, whereas the latter gains 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 purchasing foreign technology licenses, whereas 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, and the lower the spending of R&D on internal technology development, the lower is the degree of domestic technology sourcing from domestic license purchasing and relationships with local research institutions.

The remainder of the article is organized as follows. Section II develops theoretical hypotheses that link firms' technology strategies with their trade and FDI forms. Section III discusses the data and empirical methods used in our investigation. Section IV reports and interprets the empirical results. Section V concludes by summarizing the main results and drawing policy implications.

II. THEORIES AND HYPOTHESES

A. 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, whereas pure product innovation (with no changes in production processes) leads to enhanced customer value at constant costs. Pak and Park (2004) argue that new product development is expected to have more tacit and specific knowledge attributes than process skills and techniques. In this article, we consider technology choices between process innovation and 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 and 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 and Pearce (1997), in their study on technology sourcing strategies of MNE subsidiaries in the United Kingdom, find the need for MNE subsidiaries to extend their use of local technological expertise and widen their technological scope in response to global competition. In his discussion on technology strategies of Eastern European firms, Witt (1998) analyzes a wide range of technology sourcing choices including internal R&D, licensing, information networks, JVs, and acquisition. In this article, we consider technology sourcing choices as the second dimension in the firm's formulation of technology strategies.

B. *Modes of Internationalization*

Internationalization is the process of adapting firms' operations to an international environment. There are different forms of internationalization (Johanson and Vahlne 1977; Luostarinen 1980), which are shaped by a country's trade and FDI policies. In this article, 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, that is, exporting final goods assembled from imported parts and components (Feenstra 1998). In China, processing exports account for 55% of total exports to the world and 65% of exports to the United States in 2006 (Wang and Wei 2010). 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 JVs with MNEs, domestic firms may benefit technologically (Gorg and Strobl 2001). Although there are many studies that examine the technology spillover effects of FDI on domestic firms (Blomstrom and Sjoholm 1999; Buckley, Clegg, and Wang 2002), they seldom distinguish between different types of technologies (process vs. product technologies) and different sourcing strategies (internal vs. external innovations). This is one area in which this article intends to make a contribution.

C. *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 and Jensen 1999; Melitz 2003). Second, exposure to international markets facilitates learning and technology absorption (Zahra, Ireland, and Hitt 2000). Athough the causality between exporting and productivity is debatable (Clerides, Lach, and Tybout 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 produced according to the requirements of the 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 active in process innovation but not in product innovation.*

In many countries including China, processing exports are largely carried out in EPZs (Blanco de Armas and Sadni-Jallab 2002). 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 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. Although 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 because products for the world market exhibit features that are new to the domestic market. However, 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 EPZs, 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 JVs, Pak and Park (2004) develop a hypothesis based on a conflict between JV partners: the higher the degree of conflict between the JV 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 and Park (2004) argue further that the more tacit the knowledge of MNEs, the less knowledge will be transferred to JV partners. As product innovation is considered to involve more tacit and specific knowledge attributes than process innovation, we hypothesize that FDI firms have a low tendency to adopt product innovation as compared to process innovation. We summarize the above arguments in the following hypothesis.

Hypothesis 3. *FDI JVs 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 the 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 and 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 (Burpitt and Rondinelli 2000; Grossman and Helpman 1991; Zahra, Ireland, and Hitt 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 JVs are a conduit of technology transfer (Hejazi and Safarian 1999). In developing countries such as China, FDI JVs involve mainly MNEs from industrialized countries.[1] According to the OLI paradigm (Dunning 1993), foreign partners in JVs 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 and Woo (2003) argue that the greater the number of different types of technology sourcing linkages (R&D contacts, licenses, acquisitions, JVs, and minority equity ownership) pursued by the

1. FDI inflow from industrialized countries accounts for more than 50% of China's total FDI inflow in all years after 2000.

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 introduced in 1998–2000, dummy	0.501	0.500	871
NEWN	Number of new products introduced in 1998–2000	5.563	23.183	871
RDY	R&D intensity in 2000	0.029	0.098	840
MACH	Machinery import in 1998–2000, 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
EXPSH	Share of export value in total sales, 1998–1999	0.177	0.329	779
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
FORSH	Share of foreign ownership	0.140	0.257	793
GOVSH	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 (total sales) averaged over 1998–1999	0.185	1.231	779

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. However, 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.*

III. DATA AND METHODS

A. Sample

Our data comes from a World Bank survey of 1,500 firms in China.[2] The survey randomly draws 300 firms each from five major cities, Beijing, Chengdu, Guangzhou, Shanghai, and Tianjin. For our study on technology strategies, we focus on the 998 manufacturing firms and exclude the other 502 firms in service sectors. We also exclude the 111 WFOEs because their technology strategies are determined mainly by their parent companies, which is not the focus of this article. 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).

B. Dependent Variables

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

Process innovation is defined as "the adoption of technologically new or significantly improved production methods" such as "installation of machinery and equipment with improved technological performance" (OECD 2005). In the

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 inclusion of these 16 small firms.

sample period 1998–2000, introduction of computer-controlled production machines is an important process innovation for Chinese firms. Ideally, one would measure this process innovation by *newly* introduced computer-controlled production machines. Because this information is not available, we use instead the share in net value of fixed assets of computer-controlled production machines in use (AUTO). AUTO is a measure of the intensity of the firm's adoption of automatic process technology, which we consider as a proxy for the intensity of the firm's process innovation in the sample period. For the 833 firms having this data, mean value of AUTO is 0.212.

Product innovation is defined as "the implementation/commercialization of a product with improved performance characteristics such as to deliver objectively new or improved services to the consumer" (OECD 2005). The World Bank survey provides information on the number of new products introduced by the firm in 1998–2000. Based on this information, we construct two variables. NEWP is a dummy variable that equals 1 if the firm introduced new products in 1998–2000, and 0 otherwise. NEWN is the number of new products introduced by the firm in 1998–2000. We use these two variables to examine the firm's intention to carry out product innovation (NEWP) and the magnitude of product innovation (NEWN). In our sample, half of the firms introduced new products in 1998–2000 (sample mean of NEWP is 0.501). The average number of new products is 5.6 for all firms (12 for firms that introduced new products).

We use RDY as a measure of internal technology development. RDY is R&D intensity in 2000, measured by the 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 based on the survey question "Did your plant import any machinery?" MACH equals 1 if the firm imported machinery in the sample period, and 0 otherwise.[4] Sample mean of MACH is 0.38. FLIC is the total number (stock) of licenses the firm purchased from foreign firms.[5] Of the 839 firms that reported this data, 60 firms had purchased licenses from foreign firms (mean is 2.7 and maximum is 20).

We use two variables, DLIC and DRDR, as measures of domestic sourcing of technologies. DLIC is the total number of licenses the firm purchased from domestic firms. Of the 828 firms that reported this data, 143 firms had purchased licenses from domestic firms (mean is 4.9 and maximum is 36). 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 1 if the firm has such a relationship, and 0 otherwise. Sample mean of DRDR is 0.201.

C. Independent Variables

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

EXPSH is the share of export value in total sales value. We use two dummy variables to distinguish between exporting firms of different types. EXP is a dummy variable for exporting firms not located in EPZs, which mainly engage in ordinary exports. EXP equals 1 if the firm was not located in EPZs and exported in 1998 or 1999, and 0 otherwise. Sample mean of EXP is 0.254. EPZE is a dummy variable for exporting firms located in EPZs, which mainly engage in processing exports. EPZE equals one if the firm was located in EPZs and exported in 1998 or 1999, and 0 otherwise. Sample mean of EPZE is 0.116. In addition, we construct EPZN as a dummy variable for non-exporting firms located in EPZs. EPZN equals 1 if the firm was located in EPZs but did not export in 1998 and 1999. Sample mean of EPZN is 0.119.

We use three variables to capture the degree of a firm's exposure to FDI. First, FMAJ is a dummy variable for firms with majority foreign ownership. FMAJ equals 1 if the share of foreign ownership is greater than or equal to 0.5 but less than 1, and 0 otherwise. Sample mean of FMAJ is 0.208. Second, FMIN is a dummy variable for firms with minority foreign ownership. FMIN equals 1 if the share of foreign ownership is greater than 0 and less than 0.5, and 0 otherwise. Sample mean of FMIN is 0.126. Third, FORSH is the 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 FORSH is 0.14.

4. The survey does not provide information on the value of imported machinery.

5. The survey also reports the number of foreign licenses the firm purchased in 2000.

TABLE 2
Correlation Matrix

	1	2	3	4	5	6	7	8	9	10
EXPSH	1.000									
EXP	0.464	1.000								
EPZE	0.365	−0.211	1.000							
EPZN	−0.190	−0.215	−0.133	1.000						
FMAJ	0.281	0.163	0.256	−0.093	1.000					
FMIN	0.102	0.033	0.121	0.0310	−0.195	1.000				
FORSH	0.366	0.163	0.343	−0.045	0.834	0.344	1.000			
GOVSH	−0.099	−0.002	−0.063	−0.005	−0.229	−0.127	−0.247	1.000		
RDYL	0.034	−0.030	0.074	−0.012	−0.030	0.129	0.065	−0.005	1.000	
SIZEL	−0.021	0.032	0.122	−0.020	0.017	0.156	0.110	−0.050	−0.001	1.000

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

First, lagged R&D intensity (RDYL), measured by the ratio of R&D expenditure to total sales averaged over 1998 and 1999.[6] Technological innovations in both products and processes depend on the absorptive capability of the firm (Cohen and Levinthal 1990). For the 758 firms having data on RDYL, mean value equals 0.074, that is, R&D expenditure is 7.4% 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 and Klepper 1996; Yin and Zuscovitch 1998). For the 779 firms having data on SIZEL, mean value is 0.185 (million yuan).

Third, share of government ownership (GOVSH). In China, government-owned firms are found to have a lower tendency in technology innovation (Tan 2001). For the 869 firms having data on GOVSH, 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). Note that Chengdu, a city in inner China, is least open to both exporting and FDI. We use Chengdu as the base city in our regressions.

6. 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.

D. Regression Methods

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

(1)
$$Y = \beta_I + \beta_C + \beta_E(\text{export-related variables}) + \beta_F(\text{FDI-related variables}) + \beta_G\text{GOVSH} + \beta_R\text{RDYL} + \beta_S\text{SIZEL} + \varepsilon$$

In Equation (1), Y is one of the dependent variables (AUTO, NEWP, NEWN, RDY, MACH, FLIC, DLIC, and DRDR), β_I denotes the industry dummies, β_C the city dummies, and ε an error term. The right-hand side variables include independent variables of internationalization (EXPSH, EXP, EPZE, EPZN, FORSH, FMAJ, and FMIN) and control variables (GOVSH, RDYL, and SIZEL). Table 2 reports the correlation matrix of the right-hand side variables. The high correlations between EXPSH and EXP (0.464) and between FORSH and FMAJ (0.834) do not raise any concern because the respective two variables are not used in the same regression. The correlations between the other variables are low enough not to cause a serious concern about multicollinearity.

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

IV. EMPIRICAL RESULTS

A. Technology Adoption

Table 3 reports regression results on Chinese firms' adoption of automatic process technologies (AUTO) and introduction of new products (NEWP and NEWN). Regression (1) shows that the estimated coefficients on both export share (EXPSH) and foreign ownership share (FORSH) are positive and statistically significant at the 1% level, which is consistent with the findings of many studies that exporting and FDI promote technological progress of firms. In regressions (2)–(4), we find that non-EPZ exporting firms (EXP), which conduct ordinary export businesses mainly, are significantly higher in both AUTO and NEWP/NEWN than firms with no internationalization (base firm group of the regressions). We find that EPZ exporting firms (EPZE), which conduct processing export businesses mainly, have higher AUTO than non-EPZ exporting firms, but lower NEWP/NEWN 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, whereas firms of processing exports will tend to be 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 introduction of new products is hypothesized to be zero, but is found positive and significant at the 10% level in regression (4) as well as marginally significant in regression (3). The hypothesis postulates that firms of processing exports 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.

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% level, whereas 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 because products for the world market exhibit features that are new to the domestic market. However, we find from regression (2) that the estimated coefficient on EPZN is significantly lower than the estimated coefficients on EPZE. This finding suggests that non-exporting firms may 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, and FORSH), 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 (2) indicates that majority of foreign-owned firms (FMAJ) are higher by 10.8% in their intensity of adopting computer-controlled production processes (AUTO) than the benchmark group of firms with no internationalization, and minority foreign-owned firms (FMIN) are higher by 5.8%. In sharp contrast, we find from regressions (3) and (4) that FDI involvement does not have any significant effect on new product introduction (NEWP and NEWN). 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 (GOVSH), 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 GOVSH 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 and Zuscovitch (1998) argue that different innovation incentives cause the larger firm to invest more in process innovations and the small one

TABLE 3
Regression Results on Technology Adoption

	1	2	3	4
Regression Method	**OLS**	**OLS**	**LOGIT**	**OLS**
Dependent Variable	**AUTO**	**AUTO**	**NEWP**	**NEWN**
EXPSH	0.012(2.95)***			
FORSH	0.171(3.24)***			
EXP		0.079(2.85)***	0.622(2.56)**	0.345(3.10)***
EPZE		0.164(4.02)***	0.496(1.57)	0.246(1.85)*
EPZN		0.120(3.44)***	1.055(3.57)***	0.387(2.60)***
FMAJ		0.108(3.08)***	0.073(0.29)	0.180(1.35)
FMIN		0.058(1.64)*	0.300(1.12)	0.099(0.78)
GOVSH	−0.040(1.72)*	−0.040(1.77)*	0.015(0.07)	−0.058(0.61)
RDYL	0.026(5.72)***	0.027(5.75)***	5.597(1.81)*	0.004(0.17)
SIZEL	0.018(3.78)***	0.016(2.72)***	1.294(1.01)	0.027(0.96)
Electronic components	0.200(5.82)***	0.164(4.93)***	1.556(5.33)***	0.632(4.86)***
Electronic equipment	0.176(5.39)***	0.182(5.67)***	1.271(5.01)***	0.408(3.39)***
Consumer products	0.076(2.38)**	0.077(2.48)**	1.104(4.07)***	0.258(2.11)**
Vehicles and vehicle parts	0.061(2.36)**	0.077(3.10)***	1.175(4.48)***	0.516(4.15)***
Beijing	−0.024(0.92)	−0.014(0.54)	−0.240(1.01)	−0.140(1.18)
Guangzhou	−0.036(1.02)	−0.018(0.51)	−0.800(2.90)***	−0.404(3.01)***
Shanghai	0.011(0.31)	0.027(0.80)	0.067(0.24)	−0.060(0.48)
Tianjin	−0.022(0.73)	−0.004(0.14)	−0.778(2.85)***	−0.246(1.92)*
Constant	0.169(4.64)***	0.042(1.53)	−1.260(4.57)***	0.407(3.51)***
Observations	666	726	756	756
R^2	0.16	0.19		0.09
Pseudo R^2			0.12	

Notes: Base industry is the apparel and leather goods. Base city is Chengdu. Robust t-statistics in absolute value are in parentheses.

*Significant at 10%, **significant at 5%, and ***significant at 1%.

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 of 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/NEWN 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.

B. 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.

We find that exporting firms (EXP and 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 rely mainly on importing machinery and equipment from abroad (which is consistent with its focus on process innovation), whereas 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 of DLIC and DRDR are statistically insignificant for non-EPZ

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(2.06)**	1.119(4.48)***	0.280(2.71)***	0.262(0.73)	0.336(1.24)
EPZE	0.032(1.68)*	1.624(4.68)***	0.118(0.96)	0.562(0.87)	0.723(2.06)**
EPZN	0.022(2.47)**	0.222(0.80)	0.069(0.81)	−0.086(0.28)	0.817(2.71)***
FORSH	−0.047(2.45)**	1.885(4.55)***	0.318(1.72)*	−0.919(1.69)*	−1.483(2.61)***
GOVSH	−0.013(1.80)*	0.493(2.26)**	−0.113(2.40)**	−0.184(0.60)	−0.119(0.49)
RDYL	0.005(0.84)	1.613(1.08)	0.016(0.47)	0.051(0.90)	−0.045(0.95)
SIZEL	0.004(3.19)***	1.390(1.04)	0.088(3.42)***	−0.012(0.61)	0.496(1.12)
Electronic components	0.042(5.64)***	−0.276(0.93)	0.211(2.08)**	0.015(0.04)	1.263(3.82)***
Electronic equipment	0.044(3.34)***	−0.051(0.19)	0.025(0.53)	−0.096(0.29)	0.868(2.67)***
Consumer products	0.022(3.06)***	−0.837(2.69)***	0.345(2.14)**	1.172(1.93)*	0.439(1.18)
Vehicles and vehicle parts	0.030(3.45)***	−0.276(0.96)	0.252(3.41)***	−0.135(0.39)	0.454(1.35)
Beijing	−0.017(1.63)	0.125(0.51)	−0.098(1.49)	−1.102(2.92)***	−0.467(1.75)*
Guangzhou	−0.020(1.39)	0.035(0.13)	−0.216(2.20)**	−1.078(1.96)*	−0.700(2.14)**
Shanghai	−0.029(2.69)***	−0.229(0.76)	0.267(1.64)	−1.173(2.82)***	−0.705(1.96)**
Tianjin	−0.014(0.91)	−0.932(2.90)***	−0.176(2.61)***	−1.457(4.50)***	−0.965(3.04)***
Constant	0.011(1.42)	−1.250(4.81)***	−0.044(0.61)	1.728(4.52)***	−1.669(5.15)***
Observations	686	695	681	670	695
R^2	0.07		0.11	0.06	
Pseudo R^2		0.20			0.09

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

exporting firms, whereas estimated coefficient of 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 and 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. Note 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 (FORSH) is negative and statistically significant.[7] 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 and 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

7. Using FMAJ and FMIN as independent variables yield essentially the same results, which we do not report to save space.

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 FORSH 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 (GOVSH), firm R&D intensity (RDYL), firm size (SIZEL), industry dummies, and city dummies. We expect GOVSH to have a negative effect on technology development and sourcing, and find that GOVSH is indeed negatively related to R&D spending (RDY) and foreign license purchasing (FLIC). We find, however, that GOVSH 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 obtain 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 because 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.

V. CONCLUSION

Trade and FDI policies lead firms to adopt different forms of internationalization, which results in different types of technology strategies. In this article, we use a sample of Chinese firms to detect systematic relationships 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 and external development of technological capacity, and between foreign and domestic technology sourcing.

Our main finding is that different forms of internationalization have different effects on the firm's technology behavior. Consistent with many existing studies (Grossman and Helpman 1991), we find that both exporting and FDI stimulate firms to adopt more advanced process technologies. Although we find exporting to also stimulate firms' introduction of new products, we find no evidence that FDI promotes new product introduction. In a study of technology strategies adopted by JVs between western MNEs and Korean companies, Pak and Park (2004) found similar results. Moreover, we find that firms of ordinary exports gain technology strength less from process innovation and more from product innovation, whereas firms of processing exports gain technology strength more from process innovation and less from product innovation. This finding contributes to the recent literature that emphasizes the distinction between ordinary trade and processing trade (Feenstra 1998; Wang and Wei 2010).

Besides strategies of technology adoption, we find that firms with different forms of internationalization also pursue different strategies of technology sourcing. Exporting firms source technologies both internally through R&D and externally from domestic and foreign sources. This evidence suggests that exporting firms have strong incentives to enhance their technology capability, which is in line with the recent trade literature that characterizes exporting firms as the ones with high productivity (Melitz 2003). Our study also finds that firms of ordinary exports tend to obtain technologies from importing machinery and from purchasing foreign technology licenses, whereas firms of processing exports tend to rely on machinery importing but not license purchasing. In contrast, we find that FDI firms rely mainly on foreign technology sourcing.

The results from our study are useful for policy makers. Developing countries such as China place advance in technology at the top of their economic development agenda. Trade and FDI are considered as major channels of absorbing foreign technology and means of stimulating domestic innovation. Our results suggest that trade and FDI can have quite different effects on innovative activities of firms, and different forms of trade and FDI can have different effects on the type of innovations firms pursue. Our results also show that firms that engage in different types of export activities and have different levels of FDI involvement will differ in their incentives to pursue internal technology development. These results can serve as a useful reference in the design of trade and FDI policies that promote technology advance in developing countries.

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