Exporting and Innovation: Theory and Firm-Level Evidence from the People's Republic of China†

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Abstract: This paper investigates how exporting affects firm innovation in the People's Republic of China. Using firm-level data, we apply the Levinsohn and Petrin (2003) method of estimating firm productivity and matching econometrics to control for endogeneity. The results show that, on average, in contrast to non-exporters, exporters increase their R&D intensity by more than 5 per cent, raise their R&D expenditures by more than 33 per cent, and are 4 per cent more likely to engage in R&D activity. In addition, we find exporting to have a smaller impact on innovation among firms that export processed goods, specifically, those in the electronics sectors, located in coastal provinces, and foreign-owned.

Keywords: Exporting, innovation, firm heterogeneity, matching

JEL classification: D21, F14, O31

1. Introduction

A key result of Melitz's (2003) firm heterogeneity model of international trade is that exporters are more productive than non-exporters. Following the path-breaking papers of Bernard and Jensen (1995, 1999), researchers using firm-level data around the world have confirmed this finding, even within narrowly-defined sectors. Yet why exporters are more productive than non-exporters remains inconclusive. Exporters may be more productive simply because only the more productive firms export—the selection effect—exporting per se does not contribute to greater productivity. In contrast, the learning-by-exporting effect argues that exporting in itself is important because it is through learning-by-doing from other foreign competitors, suppliers and customers, that firms become productive (Wagner, 2007).[1]

To add to the debate, the role of innovation or research and development (R&D) in the relationship between exporting and productivity is much less studied—innovation is generally assumed to drive productivity, but it is seldom empirically identified and tested. Herein lies the purpose of this paper, that is, to study whether exporters do indeed innovate more than non-exporters. If exporting increases firm innovation, it should ultimately increase firm productivity.[2] This is paramount as Krugman (1992) proclaims, in the long-run, productivity is everything; a country's ability to improve its standard of living over time depends almost entirely on its ability to raise its output per worker.

In this paper, we study the case of the People's Republic of China (PRC), a transition and developing economy, which is seeking a new development approach to improve productivity and sustainability of its growth (World Bank, 2012). The gravity of this is underlined by the country's existing growth model of high investment and cheap labor that has created a whole of problems from economic (imbalance growth drivers), to social (gaping income inequality), and the environment (degradation and pollution) (Zhao, 2011). In this context, giving due attention to R&D appears to be one of the most practical strategies. Innovation is essential in moving into high value-added activity and achieving sustained growth, and investment in R&D is the key to innovation.

We first present a theoretical two-country model of how export status affects a firm's R&D activity. The model's key result shows that export status positively affect firm innovation. In the empirical analysis, in addition to performing ordinary least squares (OLS) regressions, we provide evidence of a significant positive effect of exporting on R&D among the PRC's matched firms, which attempts to solve the possible reverse causality in the OLS regressions. In particular, we find that compared with non-exporters, exporters increase their R&D intensity by more than 5 per cent, raise their R&D expenditure by more than 33 per cent, and are 4 per cent more likely to engage in R&D activity. We also find that the effect of exporting on innovation is stronger for capital-intensive sectors and domestic-owned firms, but weaker for processing-intensive sectors, electronics firms, firms in coastal regions, and foreign-owned enterprises.

The remainder of the paper is structured as follows. Section two provides a brief literature review. Section three presents some stylised facts on the state of R&D spending in the PRC, and R&D activities among PRC's exporters and non-exporters. Section four discusses the theoretical model that incorporates export status and innovation into Melitz (2003). Section five presents the empirical results. The last section concludes with policy suggestions.

2. Brief Literature Review

Economists have only recently started to investigate the relationship between exporting and innovation. Not surprisingly, the causal link between exporting and innovation remains inconclusive. Theoretical works by Atkeson and Burstein (2010) and Giammario and Licandro (2010) show that trade openness induces firms to increase innovation. Atkeson and Burstein (2010) present a general equilibrium model of the impact of a firm's decisions to operate, innovate, and engage in international trade on the marginal cost of international trade. Giammario and Licandro (2010) introduce firm heterogeneity into an innovation-driven growth model to show that trade increases firm innovation through greater competition. On the other hand, Constantini and Melitz (2008) use a dynamic model with rational expectations to show that the anticipation of trade liberalization may cause firms to bring forward the decision to innovate in order to make preparations for future export activities. In comparison to these theoretical models, our model is more straightforward where we embed innovation in the two-country model of Melitz (2003) with the aim of showing how innovation may differ between exporters and non-exporters.

Evidence from studies that examine the relationship between exporting as a driver of innovation is also mixed. A positive impact of exporting on innovation is found by Kuncoro (2012) for Indonesia, Hahn and Park (2012) for the Republic of Korea, and Ito (2012) for Japan, and Mairesse et al. (2012) for the PRC. Yet both in Hahn and Park (2012) and Mairesse et al. (2012), the authors also find a reverse causality from innovation to exporting. Other studies such as

Damijan et al. (2010) for Slovenia, Cassiman et al. (2010) for Spain, Bratti and Felice (2012) for Italy, Halpern and Murakzy (2009) for Hungary, and Palangkaraya (2012) for Australia, also find the same: innovation drives exporting.

This paper is closest to Mairesse et al. (2012) as both studies focus on the PRC. Nonetheless, it differs from Mairesse et al. in two ways. First, we provide a theoretical model to guide our empirical analysis, by embedding R&D into the Melitz (2003) firm heterogeneity model based on the framework of Helpman et al. (2010), and compare firm innovation between exporters and non-exporters. Second, we consider the possible endogeneity issue, which is ignored by Mairesse et al., to more clearly distinguish the causal effect of exporting on innovation. In particular, we employ the non-parametric matching estimation technique of Heckman et al. (1998).

3. Stylized Facts

At the macro level, there has been a rapid growth in R&D expenditure in the PRC: the country's total R&D expenditure to GDP share more than doubled in ten years to 1.4 per cent in 2007. This is quite remarkable considering that in nominal terms the economy had more than tripled in size during this period. Despite this rapid growth, the level of R&D in the PRC is still lower compared with the developed world and its neighbor, which lies between 2.5 per cent to 3 per cent of GDP (Figure 1).

At the micro or firm-level, we use a large cross-sectional database of Chinese industrial firms surveyed by the PRC's National Bureau of Statistics in 2007. The survey covers all state-owned and non-state owned firms above a designated scale. In total, there are 336,768 firms.[3] The database contains detailed information of about 100 variables, including ownership, output, value-added, exports, employment, capital stock, and intermediate inputs. Due to the limited availability of R&D information, we focus our study on the manufacturing sectors coded from 13 to 42 by the National Bureau of Statistics, which still represents a large number of 311,223 firms. For robustness, we use three different R&D indicators. The first is R&D intensity, which is the ratio of R&D expenditure to sales revenue; the second is R&D level which is the log of R&D expenditure;[4] and the last is R&D selection which is a dummy variable equal to one if a firm has positive R&D expenditure, and zero otherwise.

Overall, R&D activities in the PRC are quite low reinforcing the macro perspective (Table 1). In 2007, the average R&D intensity was less than 0.20 per cent. Only two electronics industries (40 and 41) had a R&D intensity over 1 per cent. For the medical sector (27), the R&D intensity was about 1 per cent. It is also generally observed that capital-intensive sectors innovate more than labor-intensive sectors.[5] By and large these observations also hold true for other R&D activity indicators. The average R&D expenditure per firm is about RMB1.9 million,[6] mostly concentrated at capital intensive industries, which include the electronics sectors. Interestingly, the tobacco and medical sectors also invest heavily on R&D. The low level of R&D activity is best illustrated by the R&D selection variable which shows that on average only 11 per cent of all firms engage in R&D activity.

When exporters are compared with non-exporters, exporters tend to innovate more than non-exporters (Table 2). In particular, exporters have a R&D intensity that is 11 per cent higher than non-exporters; exporters spend nearly 82 per cent more on R&D than non-exporters,[7] and 8 per cent more exporters than non-exporters invest in R&D. An interesting observation is that while the innovative activities in the electronics sectors (40 and 41) are among the highest of all the sectors (Table 1), they have a lower level of R&D intensity compared to non-exporters (Table 2). The dominance of foreign-owned exporters who are near the technology frontier in these sectors likely explains this phenomenon.[8]

4. Theoretical Model

The above stylised facts suggest that exporters are generally more innovative than non-exporters, yet the channel in which this happens—whether exporting leads innovation or innovation leads exporting—is not clear. What is of main interest is the causal relationship of exporting driving innovation, for this is key in raising a firm's productivity in the long-run. With this in mind, we build a simple theoretical model by embedding R&D into the Melitz (2003) firm heterogeneity model based on the framework of Helpman et al. (2010). The focus is on the difference in innovative activity between exporters and non-exporters. We find that exporting indeed drives innovation, but it important to account for the role of productivity in the process.

4.1 Consumer Problem

Consider a world of only two countries, home and foreign, with foreign variables denoted by an asterisk. In each country, utility (U) is defined as the consumption of a continuum of differentiated varieties of each sector and forms a constant elasticity of substitution utility, which is also the real consumption index (Q):

$$U = Q = \left[\int_{j\in J} q(j)^{\alpha} dj\right]^{\frac{1}{\alpha}}, \qquad (0< \alpha <1) \tag{1}$$

where j indexes varieties, J is the set of varieties, $q(j)$ denotes consumption of variety j, and $\frac{1}{1-\alpha}$ is the elasticity of substitution between varieties. The price index with respect to Q is defined by *P*. Solving the utility maximization problem gives the following first order demand condition:

$$q(j) = \left[\frac{p(j)}{P}\right]^{-\frac{1}{1-\alpha}} U, \tag{2}$$

where $P = \left[\int_{j\in J} p(j)^{-\frac{\alpha}{1-\alpha}} dj\right]^{-\frac{1-\alpha}{\alpha}}$ is the price index. Given the specification of sector demand, the equilibrium revenue of a firm can be expressed as:

$$r(j) = p(j)q(j) = M\, q(j)^{\alpha}, \tag{3}$$

where $M = Y^{1-\alpha}P^{\alpha}$, is a demand shifter and $Y = PU = PQ$, is income. For each firm, the demand shifter is the same—each firm supplies one of the continuum varieties and therefore measures nearly zero compared to the whole economy.

4.2 Producer Problem

Production technology of each firm is defined such that output (y) depends on total factor productivity (φ) and innovative activity (d), such as R&D investment. Labor input of each firm is normalised to unity like the case of the self-employed:

$$y = \varphi d^{\beta}, \qquad (0 < \beta < 1). \tag{4}$$

Here $0 < \beta < 1$ means that the ratio of innovation investment to output exhibits decreasing returns to scale. Given the love of variety assumption of consumers and a fixed cost of production, no firm will only serve the foreign market: if a firm is productive enough to export, it will also serve the domestic market. If a firm only produces goods for the home market, then revenue will only come from the home market: $r(\varphi) = r_h(\varphi)$. If the firm produces for both the home and foreign markets, revenue will come from both markets: $r(\varphi) = r_h(\varphi) + r_x(\varphi)$.

An exporting firm allocates its output (y) between the home market (y_h) and export market (y_x), such that the exporting firm equates the marginal revenue of both markets. From Equation (3), the marginal revenue of the home market is $Mr_h = M\alpha y_h^{\alpha-1}$ and the marginal revenue of the export market is $Mr_x = M^*\alpha\tau^{\alpha} y_x^{\alpha-1}$, where M^* is the demand shifter of the foreign country. From the equilibrium rule, $Mr_h = Mr_x$, we obtain the following formula:

$$\left(\frac{y_x}{y_h}\right)^{1-\alpha} = \left(\frac{M^*}{M}\right)\tau^{\alpha}, \tag{5}$$

where τ is an iceberg variable trade cost, such that $0 < \tau < 1$, which means export one unit good, only τ unit finally arrives in the foreign market. Besides, $y = y_h + y_x$ and $r(\varphi) = r_h(\varphi) + r_x(\varphi)$, a firm's revenue can be shown as follows:

$$r(\varphi) = \Gamma M y^{\alpha}, \tag{6}$$

where $$\Gamma = \left[1 + Ex\,\tau^{\frac{\alpha}{1-\alpha}}\left(\frac{M^*}{M}\right)^{\frac{1}{1-\alpha}}\right]^{1-\alpha}. \tag{7}$$

Ex equals 1 if a firm exports and 0 if a firm only serves the home market or does not export. Γ captures a firm's 'market access,' which depends on whether it serves only a home market or both the home and foreign markets. For a non-exporter, $\Gamma = 1$; for an exporter, Γ is another constant greater than 1.

After a firm assesses its productivity, it will choose whether or not to produce, and whether or not to export. The firm will also choose its level of innovation investment. Anticipating the outcome of innovation, the firm chooses to maximise profits. The firm bears a cost for innovation investment (d) and faces fixed entry costs (f_e), including the fixed cost for serving the home market (f_h) and the fixed cost of exporting (f_x). The firm's profit can be expressed as

$$\pi = \Gamma M(\varphi d^{\beta})^{\alpha} - d - f_e - f_h - Ex\, f_x. \tag{8}$$

The presence of a fixed cost implies that there is a zero-profit cut-off for productivity (φ_h), such that a firm with productivity below φ_h exits without producing. Similarly, the presence of a fixed exporting cost also implies that there is an exporting cut-off for productivity (φ_x), such that a firm with productivity below φ_x does not find it profitable to serve the foreign market. The firm's first-order condition for the measurement of innovation level is

$$d = (\alpha\beta\Gamma M)^{\frac{1}{1-\alpha\beta}}\varphi^{\frac{\alpha}{1-\alpha\beta}}\ . \tag{9}$$

Equation (9) shows that a firm's innovative activity is affected by its export status (Γ) and also affected by its productivity (φ).

4.3 Equilibrium

In equilibrium, the two productivity cut-offs (φ_h and φ_x) can be determined from the firm's profit problem (Equation 8) and the first order condition (Equation 9). If the firm only serves the domestic market, the profit will be zero at the equilibrium. Similarly, the cut-off productivity for exporters can be determined by the requirement that at this productivity the exporting firm profit is zero. Combining the above two conditions, we arrive at the zero cut-off condition that shows the relationship between the two productivity cut-offs:

$$\Gamma^{\frac{1}{1-\alpha\beta}}\left(\frac{\varphi_x}{\varphi_h}\right)^{\frac{\alpha}{1-\alpha\beta}} = \frac{f_h + f_e + f_x}{f_h + f_e}\ . \tag{10}$$

Equation (10) shows that the productivity cut-off of exporters (φ_x) is higher than that of non-exporters (φ_h) since $f_h + f_e + f_x > f_h + f_e$.

5. Empirical Investigation

In this section, we propose an empirical analysis of how exporting affects firm innovation based on the theoretical Equation (9) with the need to control for firm productivity. The general approach is to regress each R&D variable against export status; firm productivity; firm scale of employment; and a complete set of dummies that capture sector, province, and ownership effects. We first report results using OLS regressions and then use matching econometrics to address the possible endogeneity of exporting in the innovation regression.

5.1 Specification and Firm Productivity

Recall, we use three measures of innovation: R&D intensity, R&D level, and R&D selection. The general empirical specification is as follows, where ε is the idiosyncratic error term:

$$R\&D = C + \beta Ex + TFP + Labor + Capital + Sector + Province + Owner + \varepsilon \tag{11}$$

Ex is the export status, the main explanatory variable of interest, taking the value of one if a firm exports, and zero otherwise. Each R&D regression controls for firm productivity, employment, and capital input. In addition to firm employment (De Loecker, 2007), we also control for capital inputs as both variables can affect R&D activity and exporting.

A complete set of 28 sector dummies at the two-digit level (the food processing sector is used as the benchmark), 29 province dummies (Tibet as the benchmark), and the four firm ownership dummies: state; private; Hong Kong, China; Macao, China; and Taipei, China (HMT); and other foreign-owned firms (collective-owned firms is the benchmark), are also included. The inclusion of these dummies is motivated by the literature addressing the heterogeneity of exports in different sectors, regions, and ownership types. Feenstra and Wei (2010) show that machinery and electronics are the most important exporting sectors. Seminal papers by Krugman (1991) show that geography matters and Xu (2010) shows that the coastal provinces in the PRC account for more than 90 per cent of all exports.[9] Brandt and Li (2003) and Li et al. (2008) show that private firms face unfavorable economic and financial treatments compared with state-owned firms. In addition, Huang (2004) shows that foreign-owned firms from Hong Kong, China; Macao, China; and Taipei, China (HMT) tend to be export oriented, while firms from other countries such as the US, Japan and the European Union, focus on the Chinese domestic market.

TFP is the primary control variable of interest, which is defined as the residual (μ_i) of the following Cobb-Douglas production function:

$$y_i = \beta_0 + \beta_l l_i + \beta_k k_i + \mu_i, \qquad (12)$$

where y_i is the log of value added, defined as sales revenue minus intermediate inputs; l_i is the log of number of employees; and k_i is the log of fixed assets. A problem with the OLS productivity estimator is that it is based on coefficient estimates of capital and labor, which are likely to be biased because of the omission of the unobserved productivity shock (Olley and Pakes, 1996; Levinsohn and Petrin, 2003).[10] To address this, we employ the Levinsohn and Petrin (LP) method that uses intermediate inputs as proxies for unobserved productivity shocks, in contrast to the Olley and Pakes (1996) estimator, which uses investment. Using the LP method, the following production function is estimated: [11]

$$y_i = 0.05^{***} l_i + 0.004^{***} k_i \, . \qquad (13)$$

(0.001) (0.002) n=306,287

With this estimated production function and given each firm's labor and capital inputs, we obtain each firm's TFP to be used in Equation (11). Table 3 presents the summary statistics of the main variables used in Equation (11). Notice that there is a high level of heterogeneity of R&D expenditure across firms: the R&D intensity ranges from zero to 99 per cent, and about 11 per cent of firms invest in R&D. One-quarter of the firms is exporters. Likewise, there is also much variation in productivity levels and firm scales across firms.

5.2 OLS Results

Overall, exporting increases innovation regardless of the R&D measures. Column (1) of Tables 4, 5, and 6 show the baseline results based on the R&D measures of intensity, level and selection, respectively. Holding other variables constant, compared with non-exporters, the decision to export increases the R&D intensity by 7 per cent, lifts the R&D expenditure by nearly 42 per cent,[12] and increases the probability of R&D investment by 5 per cent.

Given that the PRC's exports vary substantially across sectors, regions, and ownership styles, it is instructive to examine how the overall finding may change when these differences are delineated. It is well known that exports from the electronics sectors account for the lion's share of the country exports, about 60 per cent of total exports (Feenstra and Wei, 2010). In terms of regional differences, more than 90 per cent of total exports are concentrated in 10 coastal provinces (Xu, 2007, 2010). And by firm type, foreign-owned firms whose owners are from Hong Kong, China; Macao, China; and Taipei, China (HMT), and others account for more than 50 per cent of the country's exports (PRC Customs Statistics, various years). Another unique feature of the country's exports is the prevalence of processing or assembly trade accounting for about half of total exports. In the electronics sectors, the share of processing exports is even higher accounting for as much as 80 per cent of the sectors' exports. Within processing exports, foreign-owned firms dominate representing as much as 80 per cent of total processing exports (PRC Customs Statistics, 2007).

The results show that the capital-intensive sectors experience a larger exporting–innovation effect, while the electronics sectors record a negative exporting–innovation effect. Column (2) of Tables 4, 5, and 6 shows, in the capital-intensive sectors, exporting increases the R&D intensity by 20 per cent, increases the R&D level by 124 per cent, and increases the probability of R&D investment by nearly 11 per cent, respectively, compared to other non-capital intensive sectors. However, for electronics, the net effect of exporting on innovation is negative, given that the positive coefficients of the exporting dummy are smaller than the negative coefficients of the interactions.

In terms of provincial differences, while the coastal regions still show a net positive effect of exporting on innovation, its effect is smaller by about 15 per cent in terms of R&D intensity, and 87 per cent in terms of R&D level, compared with the non-coastal provinces. In addition, there is an 8 per cent less chance that coastal regions will spend on R&D (see Column 3 of Tables 4, 5, and 6). In terms of ownership differences, state and private owned firms tend to innovate more than collective-owned firms, while HMT and other foreign-owned firms innovate less (Column 4 of Tables 4, 5, and 5). What is noteworthy is that even after controlling for the various ownership interaction dummies, the export status variable remains positive and statistically significant, which underlines the importance of exporting in driving innovation.

Why do foreign-owned firms and those located at the coastal provinces innovate less? A plausible explanation is provided by the technology gap theory (Gerschenkron, 1962; Fagerberg, 1994). According to this theory once a technological backward follower achieves a certain level of human capital capable of absorbing a new technology, it will start to catch-up in technological innovation. If the gap between the follower and the leader is big, the greater is the opportunity and the faster is the catch-up. While the PRC on the whole can be considered a less technologically advanced economy vis-a-vis the world's frontier of the US or Germany, in electronics, especially processing assembly of electronics, firms in the PRC is very close to the frontier. Given that the PRC's exports are dominated by processing (electronics) exports undertaken largely by foreign-owned firms located at the coastal provinces, there is likely to be very little technology gap between themselves and the foreign firms at the world's technology frontier. In fact, they may well represent the world's technology frontier in electronics assembly. As such, foreign-owned firms have less room to catch up and to innovate as compared to domestic Chinese firms.

5.3 Endogeneity and Matching Estimation

There is a major weakness in the above OLS estimations. Because of potential endogeneity, the effect of exporting on innovation cannot be really interpreted as causal, that is, to say, innovation may actually drive exporting—more innovative firms export. If we assume the reverse effect of innovation on exporting is λ and the error term is e in the reverse causality Equation, then β^{OLS} in Equation (11) can be written as:

$$\beta^{OLS} = \beta + \frac{\lambda}{1-\beta\lambda}\frac{var(\varepsilon)}{var(Ex)} + \frac{1}{1-\beta\lambda}\frac{cov(\varepsilon, e)}{var(Ex)} \quad (14)$$

The second and last terms of the right-hand side of the equation capture the simultaneity bias and omitted variable bias, respectively. If we assume the controls are able to eliminate the omitted variable bias, and since λ and the true β are hypothesized to be positive, then β^{OLS} will likely overstate the true effect of exporting on innovation. To address this problem, we use a non-parametric matching technique (Heckman et al. 1998), whereby the true effect of exporting on innovation can be interpreted as:

$$\mathrm{E}\left(RD_i^1 - RD_i^0 \middle| Ex_i = 1\right) = \mathrm{E}\left(RD_i^1 \middle| Ex_i = 1\right) - \mathrm{E}\left(RD_i^0 \middle| Ex_i = 1\right), \quad (15)$$

where RD_i^1 is the innovation measure of firm i if it exports, and RD_i^0 is the innovation measure of firm i if it does not export. In essence, Equation (15) says that the true effect is measured as the difference between the case where an exporter exports versus the case when it does not. Clearly, the second right-term in the equation $\left(RD_i^0 \middle| Ex_i = 1\right)$ —an exporter that does not export—is a counterfactual that cannot be observed. Hence, to obtain the counterfactual case, we follow the propensity score matching technique of Heckman et al. (1998).

To identify the counterfactual group, it is assumed that all differences between exporting firms and the appropriate control group (non-exporters) can be captured by a vector of observables as controlled in the regression analysis. In total, there are 78,760 exporters, and 232,463 non-exporting firms can be used as controls. A logit model is used to estimate the probability of exporting. Matching is done based on the method of the five nearest neighbors. The average of the matched firms' R&D activity can be regarded as the R&D activity of exporting firms if they were not exporting. The difference between the observed R&D variable and matched firms' R&D is the matching estimator.

To ensure a good match, it is crucial to identify treatment (exporters) and control (non-exporters) groups with substantial overlapping firm characteristics and to make a match based on those given variables, which can generate an adequate like-for-like comparison. The straightforward approach is to test the equality of a given firm's characteristics after a match between the treated group and control group based on the propensity score, and then check how large the difference is between these two groups. T-test is used to test for covariate balancing after matching in order to know whether there is still a significant difference in a given covariate between matched treated and untreated groups. A good match is evident if a given firm's characteristics are not statistically significantly different, which implies that the matched treated and untreated groups have more or less similar firm characteristics. As indicated in Table 7, the covariates between treated and untreated groups after matching the five nearest neighbours are statistically similar when the sector, province, and ownership dummies are included; although, not every variable passes the balance test. (Most absolute t-test values are smaller than two, which implies the acceptance of the null that the treated and untreated (control) groups are similar).

Overall, the different R&D measures confirm a statistical significant positive relationship of exporting on innovation (Row 1 of Table 7). In particular, compared with non-exporters, exporting increases R&D intensity by 5%, expands R&D levels by 33%, and lifts the probability of R&D expenditure by 4%, holding other determinants constant. All these estimates are significant at the 1% level. In sum, even after controlling for potential endogeneity, the magnitudes—although smaller than the OLS estimates—still show a statistical significant impact of exporting on innovation.

Different robustness checks on the matching results are also carried out by matching firms in the same sector, the same province, or the same ownership type (see columns one, two and three of Table 8, respectively). In column one, exporting firms show higher innovation in all sectors except those in electronics, while in column two, non-coastal exporting firms tend to innovate more than exporting firms in coastal provinces. Specifically, in the latter, the results are largely insignificant. In addition, in column three, domestic-owned (state, private or collective) exporting firms tend to record significant exporting-innovation effect than non-exporting domestic-owned firms, but foreign-owned exporting firms do not exhibit such effect compared to non-exporting foreign-owned firms. All these results are consistent with earlier findings.

6. Conclusions and Policy Implications

Stylised facts show that exporters are more productive and more innovative than non-exporters. However, the causal direction between exporting, innovation, and productivity remains unsettled. If exporting increases a firm's innovative activity, it will also increase the firm's productivity, which benefits the firm—by extension, the economy—in the long-run. The purpose of this paper is, therefore, to find out whether exporting does contribute to firm innovation in the PRC.

By embedding innovation in a firm heterogeneity model, we show that firm innovation is impacted by both productivity and export status. Using the PRC's firm-level data and a matching method to control for endogeneity, we find that, compared with non-exporters, exporters' R&D intensity is higher by 5 per cent, R&D level by 33 per cent, and exporters are also 4 per cent more likely to invest in R&D. In addition, more nuanced results are obtained depending on firm location, ownership, and sector. We find that among exporters engaged in processing trade, there is less of an exporting effect on innovation. In the electronics sector, in coastal provinces, and among foreign-owned firms, the exporting–innovation effect is significantly smaller than in other sectors and regions, and among collective-owned firms, respectively.

These results provide policy suggestions on three key areas. First, given that exporting helps innovation, further efforts to deepen trade liberalizations and facilitate domestic firms to enter international markets would be advantageous. Second, better protection of intellectual property rights especially in the area of enforcement should be considered. This directly addresses the main concern of many foreign firms, which if being assured will facilitate greater transfer of more advanced technology to the PRC (PRC IPR SME Helpdesk, 2012). At the same time, as Chinese firms become technology leaders in their own right, they will also benefit from better intellectual property protection.

Third, processing exports do not really foster innovation and this can be explained by the technology gap theory. Therefore, policy makers should seek to upgrade the structure of trade by increasing the amount of non-processing exports produced by domestic firms. In particular, the growth and exporting activities of private domestic firms should be facilitated. These firms comprise the backbone of the PRC's employment base and industrial output (Li et al., 2008) and they add more domestic value to exports than foreign-affiliated or state-owned firms (Koopman et al. 2012). Given the unfavorable economic and financial treatment they continue to face vis-à-vis state-owned firms (Brandt and Li 2003; Li et al., 2008), policies that encourage exporting–innovation effects can easily be introduced to reap the benefits of higher productivity to sustain economic growth. However, this process should be encouraged to evolve gradually because the processing sectors have traditionally provided jobs for much of the PRC's massive labor force, thus maintaining social and political stability.

Endnotes

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1. For developing countries as compared to developed countries, more recent studies using micro-data have tended to find a significant learning-by-exporting effect, for example, Aw et al. (2000) for the Republic of Korea, Van Biesebroeck (2005) for nine African countries,

Blalock and Gertler (2004) for Indonesia, De Loecker (2007) for Slovenia, and Park et al. (2010) for the People's Republic of China.

2. The role played by innovation in raising productivity and output growth or the endogenous growth theory has been expounded by, among others, Grossman and Helpman (1989, 1991).

3. The industry section of the *China Statistical Yearbook* was compiled based on this database. [PRC] *Markets Yearbook*, which reports the basic information of each 4-digit industry, is also based on this database.

4. We add one to make the log value of no R&D activity equal to zero.

5. Capital-intensive sectors are defined by Girma et al. (2009), see note to Table 1 for more details.

6. Calculated as $e^{0.633}$.

7. Calculated as $e^{0.598}$-1.

8. To be discussed in greater detail later in Section 5.2.

9. Beijing, Tianjin, Liaoning, Shandong, Shanghai, Jiangsu, Zhejiang, Guangdong and Fujian are considered as coastal provinces.

10. Olley and Pakes (1996) show that the OLS estimation suffers from selection bias as the unobserved productivity shocks cause some firms to exit from the market. Because the data in this paper are cross-sectional, we use a revised Levinsohn and Petrin (2003) method to estimate firm productivity, in which case we need firm-level information one year prior to estimate the production function. In addition, we control the sector effects to obtain the sector-specific productivity level.
11. For brevity, the constant term is excluded and standard error is in brackets. *** denotes the significance level at 0.01.

12. Calculated as $e^{0.350} - 1.$

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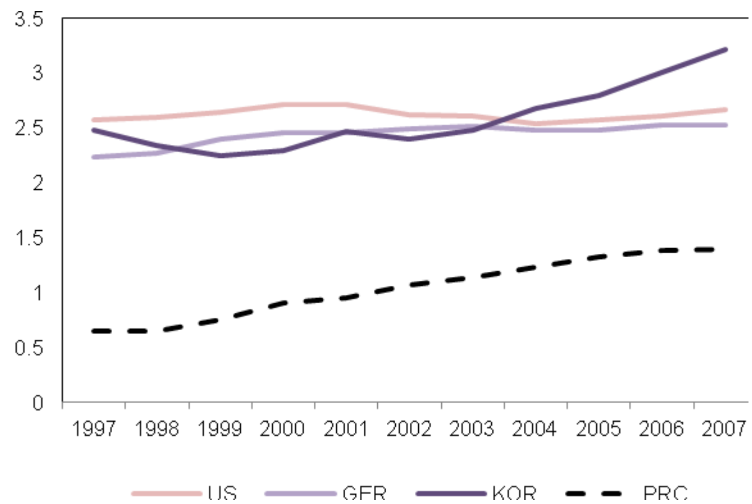

Figure 1. R&D expenditure by selected countries (per cent of GDP)

Source: World Bank, World Development Indicators. *Note*: GER = Germany, KOR = The Republic of Korea, PRC = The People's Republic of China, US = United States of America.

Table 1. R&D activity at the firm level in the PRC, 2007

Manufacturing industry (2-digit level)	Number	R&D intensity	R&D level	R&D selection
Food processing (13)	18,079	0.0658	0.3722	0.0761
Food production (14)	6,621	0.1151	0.6350	0.1328
Beverages (15)	4,405	0.1009	0.6240	0.1215
Tobacco (16)	144	0.2021	2.9709	0.3542
Textile (17)	27,818	0.0543	0.3217	0.0625
Clothing and other fibre products (18)	14,734	0.0356	0.2357	0.0478
Leather, fur, and feather (19)	7,417	0.0478	0.3928	0.0773
Timber processing (20)	7,835	0.0302	0.1738	0.0380
Furniture (21)	4,104	0.0468	0.3361	0.0663
Paper and paper products (22)	8,332	0.0435	0.2254	0.0448
Printing, reproduction of recording media (23)	5,069	0.0809	0.2727	0.0527
Culture, education and sports (24)	4,078	0.0714	0.4085	0.0841
Processing of petroleum, coking* (25)	2,141	0.0613	0.4933	0.0761
Raw chemical materials and chemical products* (26)	22,875	0.1997	0.7723	0.1370
Medicines* (27)	5,725	0.9426	2.1784	0.3534
Chemical fibres* (28)	1,550	0.1131	0.6173	0.0994
Rubber (29)	3,678	0.1394	0.5970	0.1079
Plastics (30)	15,357	0.0764	0.3290	0.0639
Non-metallic mineral products (31)	24,197	0.1025	0.3660	0.0727
Smelting and pressing of ferrous metals* (32)	7,104	0.0386	0.3160	0.0497
Smelting and pressing of non-ferrous metals* (33)	6,656	0.0779	0.5068	0.0862
Metal products* (34)	17,947	0.0763	0.3527	0.0693
General purpose machinery* (35)	26,705	0.2011	0.6901	0.1200
Special purpose machinery* (36)	13,330	0.5332	1.1339	0.1863
Transport equipment* (37)	14,033	0.3170	1.1140	0.1751
Arms and ammunition* (39)	19,280	0.2971	1.0062	0.1667
Electrical equipment and machinery*+ (40)	11,114	1.0064	1.7687	0.2586
Electronic communication equipment*+ (41)	4,500	1.1663	1.9621	0.3138
Instrumentation and meters*+ (42)	6,395	0.1467	0.4088	0.0751
All (13–42)	311,223	0.2022	0.6330	0.1102

Source: Authors' calculations.
Note: PRC = The People's Republic of China. The values in each R&D column refer to the mean. R&D intensity is defined as R&D expenditure over sales revenue in percent. R&D level is the log of R&D expenditure (plus 1 to make the log value of no R&D equal to 0). R&D selection equals 1 if a firm has positive R&D expenditure and 0 otherwise. * denotes more capital-intensive sectors as defined by Girma et al. (2009). + denotes an electronics sectors.

Table 2. R&D differences between exporters and non-exporters in the PRC, 2007

Manufacturing industry (2-digit level)	R&D intensity	R&D level	R&D selection
Food processing (13)	0.0013	0.2005	0.0351
Food production (14)	0.0394	0.4235	0.0660
Beverages (15)	0.1578	0.9331	0.1461
Tobacco (16)	0.5933	5.8868	0.5800
Textile (17)	0.0367	0.3256	0.0502
Clothing and other fibre products (18)	0.0096	0.0287	0.0001
Leather, fur, and feather (19)	–0.0057	–0.1034	0.0211
Timber processing (20)	0.0294	0.2846	0.0520
Furniture (21)	0.0098	0.1900	0.0279
Paper and paper products (22)	0.0255	0.3467	0.0511
Printing, reproduction of recording media (23)	0.0497	0.3870	0.0595
Culture, education and sports (24)	0.0083	0.1928	0.0311
Processing of petroleum, coking* (25)	0.0526	2.3318	0.2665
Raw chemical materials and chemical products* (26)	0.1750	1.1645	0.1623
Medicines* (27)	0.3943	1.7623	0.2029
Chemical fibres* (28)	0.0858	1.2576	0.1750
Rubber (29)	0.1473	0.6715	0.0828
Plastics (30)	0.0445	0.2662	0.0386
Non-metallic mineral products (31)	0.1506	0.8057	0.1423
Smelting and pressing of ferrous metals* (32)	0.1245	1.7010	0.1933
Smelting and pressing of non-ferrous metals* (33)	0.1710	1.4783	0.2118
Metal products* (34)	0.0743	0.3604	0.0541
General purpose machinery* (35)	0.2231	1.0430	0.1420
Special purpose machinery* (36)	0.4508	1.2888	0.1626
Transport equipment* (37)	0.4017	1.5280	0.1871
Arms and ammunition* (39)	0.1038	0.8983	0.1224
Electrical equipment and machinery*+ (40)	–0.3276	0.5214	0.0470
Electronic communication equipment*+ (41)	–0.4374	0.1548	0.0027
Instrumentation and meters*+ (42)	–0.0849	0.0345	0.0072
All (13–42)	0.1099	0.5981	0.0803

Source: Authors' calculations.
Note: PRC = The People's Republic of China. The numbers preceding the industry description refer to the 2-digit codes used by the National Statistical Bureau of the PRC. Differences are based on mean statistics. R&D intensity is defined as R&D expenditure over sales revenue in percent. R&D level is the log of R&D expenditure (plus 1 to make the log value of no R&D equal to 0). R&D selection equals 1 if a firm has positive R&D expenditure and 0 otherwise. * denotes more capital-intensive sectors as defined by Girma et al. (2009). + denotes electronics sectors.

Table 3. Summary statistics

Variable	Observations	Mean	Std. dev.	Min	Max
R&D intensity	311223	0.2022	1.5087	0.0000	99.0634
R&D selection	311223	0.1102	0.3132	0.0000	1.0000
R&D level	311223	0.6330	1.9418	0.0000	15.7816
Export status	311223	0.2531	0.4348	0.0000	1.0000
Log(TFP -LP)	306287	4.0562	0.9862	-5.9267	9.8681
Log(value added)	307342	8.9937	1.3704	0.0000	17.4672
Log(capital input)	310185	8.4464	1.6680	0.0000	18.0995
Log(employment)	311104	4.6087	1.0914	0.0000	12.1450

Source: Authors' calculations.
Note: R&D measures are defined as in Table 2. Log (TFP -LP) = the log value of total factor productivity estimated by the Levinsohn and Petrin (2003) method.

Table 4. OLS regression results of R&D intensity on exporting

Variable	(1)	(2)	(3)	(4)
Export dummy	0.0712***	0.0433***	0.200***	0.108***
	(0.00777)	(0.00532)	(0.0223)	(0.0157)
Productivity	0.0294***	0.0282***	0.0292***	0.0281***
	(0.00369)	(0.00368)	(0.00369)	(0.00370)
Log(employment)	0.0160***	0.0170***	0.0155***	0.0156***
	(0.00353)	(0.00354)	(0.00354)	(0.00354)
Log(capital)	0.0395***	0.0381***	0.0393***	0.0386***
	(0.00221)	(0.00223)	(0.00221)	(0.00222)
Export×Cap-int		0.161***		
		(0.0144)		
Export×Electronics		-0.437***		
		(0.0423)		
Export×Coastal			-0.152***	
			(0.0231)	
Export×State				0.191***
				(0.0576)
Export×Private				0.00304
				(0.0159)
Export×HMT				-0.159***
				(0.0244)
Export×Foreign				-0.117***
				(0.0248)
Constant	-0.530***	-0.510***	-0.534***	-0.516***
	(0.0345)	(0.0349)	(0.0343)	(0.0346)
Sector effects	Yes	Yes	Yes	Yes
Province effects	Yes	Yes	Yes	Yes
Ownership effects	Yes	Yes	Yes	Yes
Observations	306287	306287	306287	306287
R-squared	0.055	0.056	0.055	0.055

Source: Authors' calculations.
Note: HMT=Hong Kong, China; Macao, China, and Taipei,China. R&D intensity is defined as the ratio of R&D expenditure to sales. Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 5. OLS regression results of R&D level on exporting

Variable	(1)	(2)	(3)	(4)
Export dummy	0.350***	0.127***	0.883***	0.370***
	(0.0104)	(0.0105)	(0.0307)	(0.0217)
Productivity	0.241***	0.238***	0.240***	0.235***
	(0.00372)	(0.00371)	(0.00372)	(0.00372)
Log(employment)	0.277***	0.278***	0.274***	0.274***
	(0.00447)	(0.00446)	(0.00446)	(0.00446)
Log(capital)	0.191***	0.185***	0.191***	0.187***
	(0.00267)	(0.00266)	(0.00267)	(0.00267)
Export×Cap-int		0.680***		
		(0.0221)		
Export×Electronics		-0.769***		
		(0.0412)		
Export×Coastal			-0.627***	
			(0.0322)	
Export×State				1.610***
				(0.0820)
Export×Private				0.0566**
				(0.0241)
Export×HMT				-0.363***
				(0.0305)
Export×Foreign				-0.256***
				(0.0318)
Constant	-3.777***	-3.674***	-3.794***	-3.684***
	(0.0424)	(0.0420)	(0.0423)	(0.0422)
Sector effects	Yes	Yes	Yes	Yes
Province effects	Yes	Yes	Yes	Yes
Ownership effects	Yes	Yes	Yes	Yes
Observations	306287	306287	306287	306287
R-squared	0.172	0.177	0.174	0.177

Source: Authors' calculations.
Note: HMT=Hong Kong, China; Macao, China, and Taipei,China. R&D level is the log of R&D expenditure (plus 1 to make the log value of no R&D equal to 0). Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 6. OLS regression results of R&D selection on exporting

Variable	(1)	(2)	(3)	(4)
Export dummy	0.0504***	0.0256***	0.115***	0.0567***
	(0.00166)	(0.00182)	(0.00440)	(0.00321)
Productivity	0.0292***	0.0288***	0.0291***	0.0285***
	(0.000574)	(0.000573)	(0.000574)	(0.000574)
Log(employment)	0.0350***	0.0352***	0.0347***	0.0347***
	(0.000688)	(0.000687)	(0.000687)	(0.000687)
Log(capital)	0.0252***	0.0245***	0.0251***	0.0247***
	(0.000420)	(0.000421)	(0.000420)	(0.000420)
Export×Cap-int		0.0817***		
		(0.00337)		
Export×Electronics		-0.114***		
		(0.00601)		
Export×Coastal			-0.0758***	
			(0.00461)	
Export×State				0.171***
				(0.0105)
Export×Private				0.00941***
				(0.00358)
Export×HMT				-0.0600***
				(0.00470)
Export×Foreign				-0.0432***
				(0.00477)
Constant	-0.468***	-0.455***	-0.469***	-0.457***
	(0.00609)	(0.00609)	(0.00609)	(0.00610)
Sector effects	Yes	Yes	Yes	Yes
Province effects	Yes	Yes	Yes	Yes
Ownership effects	Yes	Yes	Yes	Yes
Observations	306287	306287	306287	306287
R-squared	0.123	0.127	0.125	0.126

Source: Authors' calculations.
Note: HMT=Hong Kong, China; Macao, China, and Taipei,China. R&D selection equals one if a firm has positive R&D expenditure and zero otherwise. Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 7. Matching results: Different measures of innovation

	R&D intensity	R&D level	R&D selection
Nearest neighbor	0.0527*** (0.0095)	0.2860*** (0.0137)	0.0394*** (0.0021)
Balancing test	Treated	Control	T-test
Productivity	3.9800	4.0000	-1.40
Log(employment)	5.2100	5.1800	1.47
Log(capital)	8.8500	8.8300	1.94
Sector14	0.0160	0.0190	1.04
Sector15	0.0050	0.0065	-4.08
Sector16	0.0004	0.0003	0.87
Sector17	0.1050	0.1090	-2.34
Sector18	0.1000	0.1040	-1.45
Sector19	0.0480	0.0510	-2.80
Sector20	0.0187	0.0186	0.11
Sector21	0.0220	0.0200	1.02
Sector22	0.0114	0.0111	0.53
Sector23	0.0070	0.0070	1.65
Sector24	0.0330	0.0300	2.13
Sector25	0.0010	0.0009	0.05
Sector26	0.0490	0.0510	1.92
Sector27	0.0132	0.0148	-2.68
Sector28	0.0031	0.0031	-0.06
Sector29	0.0130	0.0130	0.69
Sector30	0.0514	0.0465	4.41
Sector31	0.0396	0.0391	0.51
Sector32	0.0073	0.0071	0.58
Sector33	0.0102	0.0103	-0.18
Sector34	0.0620	0.0610	0.96
Sector35	0.0680	0.0650	2.72
Sector36	0.0370	0.0370	-0.30
Sector37	0.0390	0.0400	-1.91
Sector39	0.0730	0.0680	4.17
Sector40	0.0700	0.0640	4.59
Sector41	0.0200	0.0200	1.80
Sector42	0.0450	0.0480	-1.25
Beijing	0.0160	0.0170	-1.12
Tianjin	0.0220	0.0220	0.30
Hebei	0.0166	0.0161	0.72
Shanxi	0.0027	0.0024	1.15
Inner Mongolia	0.0020	0.0020	0.46
Liaoning	0.0330	0.0310	1.53
Heilongjiang	0.0030	0.0030	-0.35
Shanghai	0.0570	0.0570	0.15
Jiangsu	0.1255	0.1282	-1.63
Zhejiang	0.2620	0.2730	-4.85
Anhui	0.0130	0.0140	-1.41
Fujian	0.0660	0.0770	-8.83

Jiangxi	0.0087	0.0097	-1.94
Shandong	0.0777	0.0759	1.35
Henan	0.0070	0.0070	0.03
Hubei	0.0090	0.0090	0.32
Hunan	0.0102	0.0099	0.52
Guangdong	0.2330	0.2130	1.48
Guangxi	0.0070	0.0070	0.30
Chongqing	0.0049	0.0046	1.06
Sichuan	0.0090	0.0090	0.34
Guizhou	0.0012	0.0012	0.16
Yunnan	0.0030	0.0030	-0.13
Shaanx	0.0030	0.0030	1.00
Qinghai	0.0002	0.0002	0.46
Ningxia	0.0008	0.0008	0.20
Xinjiang	0.0010	0.0010	-0.20
State	0.0282	0.0288	-0.71
Private	0.4050	0.4110	-1.76
HMT	0.2370	0.2300	1.72
Foreign	0.2640	0.2760	-5.84

Source: Authors' calculations.
Note: Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1. R&D intensity is defined as R&D expenditure over sales revenue in percent. R&D level is the log of R&D expenditure (plus 1 to make the log value of no R&D equal to 0). R&D selection equals 1 if a firm has positive R&D expenditure and 0 otherwise. "Treated" refers to exporters and "Control" denotes non-exporters. The balancing test values are the mean statistics of each variable in the treated and control groups. HMT=Hong Kong, China; Macao, China, and Taipei,China.

Table 8. Matching results with R&D intensity as the dependent variable: Matching criterion by the same sector, province or ownership type

Sector	Estimator (1)	Std. Error	Province	Estimator (2)	Std. Error	Ownership	Estimator (3)	Std. Error
Sector13	0.001	(0.019)	Beijing	0.324	(0.246)	State	0.150*	(0.106)
Sector14	0.043*	(0.026)	Tianjin	-0.028	(0.079)	Private	0.132***	(0.011)
Sector15	0.158***	(0.055)	Hebei	0.078***	(0.031)	Collectively	0.149***	(0.032)
Sector16	0.578**	(0.294)	Shanxi	0.429**	(0.224)	HMT	-0.174	(0.028)
Sector17	0.032***	(0.008)	Inner Mongolia	0.207**	(0.102)	Foreign	0.013	(0.026)
Sector18	0.006**	(0.003)	Liaoning	0.033	(0.042)			
Sector19	0.019**	(0.008)	Heilongjiang	0.19***	(0.013)			
Sector20	0.031***	(0.014)	Shanghai	0.033	(0.048)			
Sector21	0.023**	(0.012)	Jiangsu	0.006	(0.020)			
Sector22	0.026	(0.025)	Zhejiang	0.090***	(0.015)			
Sector23	0.068*	(0.038)	Anhui	0.079***	(0.013)			
Sector24	0.006	(0.006)	Fujian	0.042	(0.036)			
Sector25	0.080*	(0.058)	Jiangxi	0.042***	(0.005)			
Sector26	0.160***	(0.028)	Shandong	0.062***	(0.015)			
Sector27	0.29*	(0.18)	Henan	0.266***	(0.069)			
Sector28	0.056	(0.071)	Hubei	0.211***	(0.082)			
Sector29	0.105**	(0.046)	Hunan	0.33***	(0.074)			
Sector30	0.015*	(0.008)	Guangdong	-0.01	(0.019)			
Sector31	0.133***	(0.031)	Guangxi	0.046	(0.085)			
Sector32	0.188*	(0.054)	Chongqing	0.452***	(0.143)			
Sector33	0.131***	(0.039)	Sichuan	0.177*	(0.141)			
Sector34	0.154***	(0.015)	Guizhou	1.001*	(0.688)			
Sector35	0.129***	(0.026)	Yunnan	0.314***	(0.112)			
Sector36	0.360***	(0.080)	Tibet	0.240*	(0.127)			
Sector37	0.188***	(0.063)	Shaanxi	0.774***	(0.262)			
Sector39	0.128***	(0.046)	Qinghai	0.359**	(0.160)			
Sector40	-0.328**	(0.131)	Ningxia	0.302**	(0.152)			
Sector41	-0.462**	(0.181)	Xinjiang	0.212*	(0.141)			
Sector42	-0.132**	(0.060)						

Source: Authors' calculations.
Note: Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1. R&D intensity is defined as R&D expenditure over sales revenue in percent. Sectors 32 to 39 are the capital intensive sectors. Sectors 40, 41, and 42 are the electronics sectors Beijing, Tianjin, Liaoning, Shandong, Shanghai, Jiangsu, Zhejiang, Guangdong and Fujian are considered as coastal provinces. HMT=Hong Kong, China; Macao, China, and Taipei,China.