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The Role of Small Firms in China's Technology Development

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THE ROLE OF SMALL FIRMS IN CHINA'S TECHNOLOGY DEVELOPMENT

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Abstract

Science & Technology (S&T) is high on the Chinese policy agenda but there are large uncertainties on the actual S&T development. For instance, previous studies tend to focus only on large and medium-sized enterprises (LMEs). The situation in Chinese small firms is far less explored. This paper aims to examine the role of S&T-based small firms. More precisely, we examine how much S&T that has been accounted for by small firms and how their S&T intensity differs across industries and ownership groups. We also analyze how various firm characteristics differ over size categories and S&T status. This study is based on newly processed micro level data provided by the National Bureau of Statistics with information on a large number of S&T indicators for small-, medium-, and large-sized manufacturing firms in China in 2000 and 2004. Our results suggest that small firms in Chinese S&T resemble their role in many other countries. They account for a comparably small share of total S&T and most small firms are not engaged in any S&T. However, those small firms that do engage in S&T tend to be more S&T intensive and have a higher output in terms of patents than larger Chinese S&T firms.

JEL codes: O30, O31, O53
Keywords: Technology, SMEs, China, S&T, R&D

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1. INTRODUCTION

Science & Technology (S&T) is high on the Chinese policy agenda. In the recently released National Guidelines for Medium- and Long-term Plans for Science and Technology Development (2006-2020) of China, S&T is considered the key driving force for sustainable economic growth and for a transformation of China to an innovation-oriented nation within the next 15 years. (Chinese Ministry of Science & Technology, 2006).

The official rhetoric and emphasis on S&T seems to be reflected in large increases of S&T efforts as witnessed by, for instance, rapidly growing expenditures on research and development (R&D). As a result, China has become the world's third largest performer of R&D, just behind the U.S. and Japan, which has received much domestic and international attention.[1] Moreover, China is rapidly transforming its R&D structure where the business sector has become the largest R&D performer in China. The share of business R&D in total R&D expenditures has surpassed 60 percent since 2003, which makes China similar to OECD countries in terms of R&D by performing sector (OECD, 2005a).

Still, there are remaining uncertainties on the actual S&T development in China. Previous studies tend to focus only on large and medium-sized enterprises (LMEs), and the situation in these enterprises is relatively well documented in statistical publications (e.g. National Bureau of Statistics, 2004) as well as in academic ones (e.g. Jefferson et al., 2003). The situation in small Chinese firms is far less explored. There is to this date no comprehensive analysis of S&T activities in these small firms because little data has been available. This is unfortunate considering their potential importance for S&T development, and the indispensable need for reliable information in S&T policy decision-making.

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As a main contribution to the existing literature on S&T development in China, this paper aims to examine the role of small S&T-based firms. More precisely, we examine how much S&T that has been accounted for by small Chinese firms and how their S&T intensity differs across industries and ownership groups. We also analyze how various firm characteristics differ between small firms with and without S&T activities, and LMEs with S&T. This study is based on newly processed micro level data provided by the National Bureau of Statistics with information on a large number of S&T indicators for small-, medium-, and large-sized Chinese manufacturing firms in 2000 and 2004.

We find that small Chinese firms account for about 90 percent of all firms and about 67 percent of all firms with any S&T activity. However, large firms conduct most S&T in absolute terms and small firms account for about 14 percent of total R&D expenditures, a figure that is roughly the same as in many other countries. Most small Chinese firms do not engage in S&T but those who do tend to be more S&T intensive than large- or medium- sized firms with S&T. Again, a result that corresponds to previous studies on other countries. We also find small firms with S&T to have higher productivity and capital intensity than other small firms but, perhaps unexpectedly, that they have a lower export ratio. Finally, S&T output in terms of patents tends to be relatively high in small firms but their ability to use S&T to develop new products for the domestic- or foreign market tends to be relatively weak.

The remainder of this paper is organized as follows. In Section 2, we present some theoretical arguments for, and empirical evidence of, the potential importance of small firms in technology development and also a discussion on Chinese policies towards small firms. The description of data used in this paper is given in Section 3. An overview of S&T in the Chinese manufacturing sector, with an emphasis on size-related differences is presented in Section 4. The

[1] This rank is based on a conversion of Chinese currency into USD PPP.

analysis of the role played by small firms is presented in Section 5. Section 6 focuses on a comparison between S&T-based small firms and non-S&T small firms, as well as LMEs with S&T. We conclude in Section 7.

2. S&T ACTIVITIES IN SMALL FIRMS

Previous Studies

Theories on industrial evolution link small firms to economic growth through their roles in creation and diffusion of knowledge and technology (See e.g. Jovanovic, 1982, 2001; Hopenhayn, 1992; Audretsch, 1995; Ericson and Pakes, 1995; Klepper, 1996). Small firms are typically assumed to be able to develop new technologies and compete with already established firms. Uncertainty of future profits makes the new firms enter the market at a small scale. If successful, the firm will expand its production, but it will leave the market if it is unsuccessful when competing with older firms.

In particular, Roberts and Weitzman (1981) and Lambson (1991) have constructed models with uncertainty of the cost-effectiveness of different technologies; Pakes and Ericson (1998) and Pakes and McGuire (1994) construct models with learning externalities and imperfect competition; and Cooper et al. (1999) a model with technology embodiment. These models show that new small firms can invest in new technology. The outcome of the investment is uncertain and results in a pattern of entry and exit of firms, which is important for the growth of the technology capacity and of the economy.

Hence, there are a number of theoretical models which explain a dynamic industry evolution where firms enter and exit the market. It is also clear from the theoretical literature that the technology capacity in small firms is of crucial importance for this industrial development.

According to most empirical studies, the larger a firm the more likely it is to be engaged in innovation activities, such as R&D. However, there is evidence, in particular among some EU-15 member countries, that small S&T-based firms invest relatively more in R&D (or other innovation activities) than their larger counterparts, measured by the ratio of R&D expenditure to turnover (European Commission, 2004). Thus, it may be rarer for small firms to engage in R&D, but when they do, their R&D efforts are relatively high.

About 30-60 percent of small manufacturing firms in the OECD countries have introduced new or improved products or processes and are considered to be innovative (OECD, 2005a). Small firms are also conducting a growing share of R&D in most OECD countries, but are still lagging behind large firms. Small firms' share of total R&D is around 17 percent in the OECD countries (OECD, 2005b). Moreover, the relative importance of small firms tends to be high in small countries, and low in large ones.

S&T seems to have a positive impact on the performance of small firms. For instance, a study on ten EU countries suggests that small firms engaged in S&T tend to have a relatively high degree of internationalization: 65 percent of these firms operate internationally with an export share of turnover of 19 percent (European Commission, 2003).

The experience in other transition economies is perhaps of special interest for China. In European transition economies, new opportunities have emerged, and the competitive pressure increased, as a result of the transition process. As a consequence small firms are seen to play an increasingly important role in terms of production and employment. In these transition economies, small firms' share of total turnover has reached 14 -31 percent and their share of the total labor force has reached 15 -20 percent (Schwaag Serger and Hansson, 2004). However, the majority of small firms are still very young establishments with low productivity levels. Moreover, the proportion of innovative small firms in these countries is between 17-36 percent, which is lower

than in the EU-15 member countries. On the other hand, small firms in these transition economies are more export-oriented than their counterparts in the EU-15 member countries, and they account for 20-44 percent of total exports (where small firms account for less than 20 percent of exports in EU-15 member countries). However, the export capacity in these firms depends largely on foreign investment and technology instead of indigenous innovation (Schwaag Serger and Hansson, 2004).

Looking at relevant experience from East Asia, it seems fair to say that most economies in the region have benefited from an S&T-based development but the strategy for technology development and the role played by small firms differ across countries. For instance, with strong government support and large-scale introduction of foreign technology, small high-tech firms have been the key driving force in Taiwan's economic development. However, this central role of small firms might be about to change. R&D expenditures by manufacturing small firms have increased steadily over the last decade, but their rate of growth has been slower than in large firms. The proportion of total R&D expenditure accounted for by small firms has therefore fallen, from above 35 percent in the 1990s to 28 percent in 2000 (Ministry of economic affairs, Taiwan, 2005).

As an example of a different strategy, the technology development has traditionally been driven by large corporations, in a highly concentrated industrial structure, in both Japan (keiretsu) and South Korea (chaebol). In Japan, small firms'share of total R&D expenditures was only 14 percent in 1990 and increased slightly to 15 percent in 2002. (UNESCO, 2005). In recent years, the role of small firms in South Korea has undergone a dramatic and surprising change, with large increases in their shares of R&D, export, and even outward direct investment. Their share in the total business R&D has increased from 13 percent in 1995 to 27 percent in 2001 (Suh, 2004).

In addition, while small Japanese firms are highly home-market oriented, small firms from Taiwan have been traditionally focused on foreign markets (La Croix, 2006). The general lesson

from the above East Asian economies is that competition in export markets provides the necessary incentive for small firms to upgrade their technology standard. With government support and within a favorable regulatory and investment framework, small firms tend to be more S&T-based.

In later Asian developers, such as Malaysia, Thailand, Indonesia and the Philippines, small firms are often highly export-oriented in labor-intensive processing industries. But their innovation potentials are limited by both R&D investment and human resources at a comparatively low level (UNESCO, 2005).

The Chinese Context

The importance of small firms in China is closely associated with internal structural adjustment and intensified domestic and international competition faced by industrial firms. Since the mid 1990s, the large increase of small non-state-owned firms has not only changed the ownership structure of the Chinese industrial sector, but also accelerated the process of privatization and the transformation towards a more market-oriented economy. There is a large presence of small firms in key industries such as automotive, electronics, textile and garments, pharmaceutical products, and information technologies, which implies that the capacity-building and competitiveness enhancement of small firms will have a strong impact on the industry as a whole. Concerning the labor market, associated with the structural reforms, small firms are the main destination for workers laid-off from state-owned firms (SOEs) that re-enter the labor market. Finally, the urbanization process and enlarged higher education enrolment have increased the job creation pressure, even in the labor market for skilled labor, where small S&T-based firms can potentially absorb the rapidly increased human resource of S&T and provide a platform for entrepreneurship and innovation activities.

However, Huang et al. (2004, p.377) suggest that in comparison to OECD countries, small Chinese firms have not been sufficiently supported to carry out R&D. Moreover, while they play an important role in job creation and enhancement of competition, they are often in a weak position in terms of access to many important resources such as information, technology, skilled labor, and financing. Against this background, the Chinese government is taking various measures to promote the developments of small firms. The Small and Medium-sized Enterprise Promotion Law was adopted in 2003, which aims at improving their access to bank lending and the credit guarantee system. It offers governmental support to small firms in a broad range of fields such as financial and consulting support, technical innovation, market exploration and social service (INNOFUND, 2003). Moreover, the Chinese government provides small S&T-based firms with direct funding and tax incentives and encourages new start-ups through e.g. high-technology incubators and S&T parks. Despite the achieved progress and improvements, major structural and policy-related obstacles remain. For instance, the current financial market with few financing channels and lacking of small- and non-governmental banks create huge difficulties for small firms in China to fund their S&T activities. (Wang, 2004). Also, small firms are prevented from entering the international market, as most of them are not authorized to engage in imports and exports (Chen, 2004).

3. DATA DESCRIPTION

The data used in this paper are from the National Economic Consensuses and compiled by National Bureau of Statistics of China (NBS). The general industry statistics and S&T indicators have been collected annually for large and medium-sized firms from 1985 onwards. For small firms, information on S&T activities is available for 2000 and 2004.

The variables included in the dataset are from two different sources. The first one is balance sheets of firms from industrial statistics. The data structure in this dataset is very similar to financial accounts of firms applied in previous empirical studies on a range of different countries. The other source is S&T statistics. Merging these two datasets and using unique firm identification codes, we obtain a dataset containing variables, which can be divided into three categories: 1) Firm-level economic variables, such as employment, sales, value-added, exports, fixed assets; 2) S&T inputs such as R&D expenditure, R&D personnel, technology imports; 3) S&T outputs, such as patents, new product- and high-tech exports.

The classification of firms by size in the statistical survey system of China has been subject to several revisions. The classification of Large-, Medium- and Small-sized firms applied in this paper, seen in Table 1, is the latest updated version from 2004, in which employment, turnover and fixed asset are taken into account as a combined firm-size indicator.[2] The size categories for 2000 have been reclassified according to the new standard from 2004.

Table 1 about here

Regarding the industry aggregation, in this paper we focus on the total manufacturing sector, some high-tech industries, and industries at the 2-digit level according to an industry classification, which is similar to the classification of ISIC, Rev. 3.

For the comparison across various ownership groups, we follow the classification applied by Jefferson et al. (2003), and Hu et al. (2005) in their previous analyses of S&T activities in

[2] There is no standard definition of small firms across different countries, which makes the international comparison difficult. Small firms are generally considered to be non-subsidiary, independent firms, which employ fewer than a given number of employees and are above certain financial thresholds. 250 employees are the upper limit in the European Union and 500 employees in the US. Moreover, the financial ceiling for medium enterprises is defined at the level of Euro 50 million, and 10 million for small enterprises in the new EU standard classification.

Chinese LMEs (The detailed ownership categories are given in Table 9). Such classification enables us to highlight the most important ownership categories of small firms, and makes a comparison with previous studies on LMEs feasible.

4. S&T IN THE CHINESE MANUFACTURING - AN OVERVIEW

General trend

The strong expansion of S&T in China is seen in Table 2. All S&T indicators have increased, often more than doubled, between 2000 and 2004. For instance, S&T expenditures have increased by 138 percent and R&D expenditures by 170 percent (current prices).

The S&T expenditures discussed above include wages for personnel, and purchases of fixed assets and raw materials. There are obviously other measures for Chinese firms to improve upon technology, some of them are presented in the table. For instance, expenditures on technological renovation are even larger than total S&T expenditures. Moreover, expenditures on other types of S&T activities, such as import of technology or purchase from other domestic actors, have also increased. Interestingly, import of technology has increased only modestly, in comparison to the high growth in other indicators. It is also worth to point out that expenditures on import of technologies is substantially less than expenditures on own technological development, suggesting that the often voiced concern of a dependence on imported technologies might not be serious. However, it should also be pointed out that this concern is often based on a correct observation that Chinese import is more technology intensive than Chinese export.

The number of S&T personnel has also increased, although at a lower rate than S&T expenditures. S&T personnel are divided in three categories: with or without formal qualifications

(primarily education), and R&D personnel. The latter is the most qualified subgroup.[3] It is primarily the R&D personnel or employees with little formal qualifications that have increased.

Table 2 about here

All of the above figures measure inputs in S&T. Output of S&T is typically more difficult to measure but one indicator is the number of patents. As seen in the table, patent applications are relatively few but increase rapidly, confirming previous results that the growth in patents in China between 2003 and 2005 is the highest in the world (WIPO, 2006). Another measure on S&T output that is often used in R&D/innovation surveys is the introduction of new products. The assumption is that S&T will materialize in new products.[4] The drawbacks with this measure are, firstly, that new products might materialize without any formal S&T and secondly, that S&T might aim at improving already existing products or processes, rather than developing new ones. Bearing these caveats in mind, we see in Table 2 that sales and exports of new products increased substantially over the period. It is also worth mentioning that most products are sold only on the domestic market.

To sum up the discussion above, it is seen that China is rapidly increasing its S&T activities. There are two different explanations, with very different implications to this development. The first one is that the growth in S&T is only a reflection of the general rapid development of the Chinese economy. In other words, in a country growing with almost 10 percent annually, and where S&T are growing from low levels, the previously seen development might be natural and only what one could expect for a country like China. If this description is

[3] Note that the three subgroups do not sum up to total S&T personnel since S&T personnel are based on exact head count, while R&D personnel are based on so called "full time equivalence" in accordance with OECD standards.

correct, the structure of the Chinese economy should remain largely unchanged. The second possible explanation is that these figures reflect a structural change of Chinese industry with an increased S&T intensity. One way to further examine the issue is therefore to examine S&T intensities within Chinese firms.

Table 3 shows technology intensities. The figures do not support the hypothesis of a strong expansion of S&T within Chinese firms: S&T intensities have increased modestly or even been stable. For instance, the share of firms with any S&T increased from 12 to 15 percent but the overall S&T intensity, measured as S&T expenditures as a share of sales, was stable at around 1.2 percent. The implications are, firstly, that an overwhelming share of Chinese firms do not engage in any S&T, and secondly, that although S&T expenditures have been growing rapidly in China (Table 1) they have only matched the growth in sales, leaving the overall S&T intensity almost constant.

Other technological efforts, such as import, renovation, efforts on absorption, or domestic purchases, have also shown relatively small changes. The largest change is the decline in import of technology, suggesting again, a slight decline in the dependence on foreign technologies. The last input measure shows a decline in the share of S&T personnel. The development differs, however, between different types of S&T personnel.

The number of patents is, as previously mentioned, still relatively low in China but growing, and Table 3 shows that there is a strong growth in patent intensities in Chinese firms. For instance, the number of patent applications per 100 employees increased from 0.04 to 0.10 and similar growth is seen in the other measures on patenting.

Table 3 about here

[4] In the Chinese statistics, new products refer to products new to the firm, rather than new to the market.

Finally, the introduction of new products has increased over the period. The growth of new products for export is particularly high, but most products are still sold only on the domestic market.

The conclusion from Table 3 is that the S&T intensity in Chinese industrial firms does not seem to have increased between 2000 and 2004. However, structural changes of the Chinese economy could explain the pattern observed in Table 3. For instance, if the relative importance of low-tech industries has increased during the studied period, the result would be an overall stable S&T intensity even if the intensity would increase in individual firms. One way to control for this possibility is to examine the issue at a sector level, which is done for a selection of industries in Table 4.

As shown in Table 4, the R&D intensities in most but not all of the high-tech industries were higher than the average R&D intensity in manufacturing. R&D was roughly 2 percent of value added on average in Chinese manufacturing in 2003 and 4.4 percent in high-tech industries. In an international comparison to the U.S. and Japan, the difference is remarkable. For instance, the R&D intensity in 2001 in high-tech industries was more than five times higher in the US and Japan than in China. The results suggest that “high-tech” industries are not very technology intensive in China.

More importantly, R&D as a share of value added has either declined or been relatively stable between 2001 and 2004, not only in manufacturing in general but also in high-tech industries.

Table 4 about here

5. THE ROLE OF SMALL FIRMS

The discussion in section 3 suggests that small firms can be important in countries' industrial transformation. One may ask whether this can also be the case in China. Table 5 shows the relative importance of firms of different size categories in the Chinese economy in general, and in S&T in particular.

Around 90 percent of Chinese firms are small, and the share has increased slightly over the period. Medium sized firms account for roughly 10 percent of the number of firms, and large ones for only about 1 percent. The figures on shares of the economy give a very different picture where each of the three different size categories accounts for around one third of value added and sales in 2000 as well as in 2004. The shares for capital and labor are very different and there have been large changes over the period. Large firms accounted for around 44 percent of the capital stock but only around 22 percent of the employment in 2000. Small firms, on the other hand, accounted for around 44 percent of employment but only around 16 percent of the capital stock. Hence, large firms are substantially more capital intensive than small firms. This is true also in 2004 but to a slightly lesser extent: the small firms' share of employment increase to around 47 percent and their share of the capital stock increased with a dramatic 10 percentage points to around 26 percent. Export, finally, shows an opposite trend where the share of large firms increase from 22 percent in 2000 to around 33 percent in 2004. Medium sized firms still account for the largest share of export.

Moving to figures on S&T we see that S&T activities are substantially more concentrated in large firms than any other economic activity discussed above. Large firms increased their share of S&T expenditures from around 44 percent in 2000 to over 50 percent in 2004. Small firms are only accounting for around 17 percent of all S&T expenditures and 14 percent of all R&D expenditures. The result is very similar to the distribution of R&D expenditures over size

categories in many other countries. As previously discussed, small firms account for an average of 17 percent of all R&D expenditures in the OECD countries (OECD, 2005a). In comparison with East Asian economies, the importance of S&T in small Chinese firms is similar to the experience in Japan and (previously) Korea but is substantially smaller than in Taiwan.

Table 5 about here

Other types of S&T, such as purchases of foreign or domestic technology, are also concentrated in large Chinese firms. This suggests that different types of S&T activities are complements rather than substitutes, which has also been suggested by Hu et al. (2005) who examine productivity effects from different technology sources. In other words, it seems to be the same group of firms that conduct own R&D, import technology from abroad, and purchase it from other domestic actors.

Employment shares are, again, showing that most S&T personnel work for large firms, around 39 percent in 2000 and 44 percent in 2004. Patents, finally, show a slightly different pattern and each size category accounts for around one third of patent applications, which resembles the distribution of sales and value added across different size categories. This suggest that R&D productivity, as measured by the number of patent per S&T input, is highest among small Chinese firms and lowest among large Chinese firms. The other output measure on S&T tells a very different story, where small firms account for a very small share of new products sold on the domestic market or as export. This suggests that small firms face problems in materializing their S&T activities into new products.

The S&T intensities in Chinese firms of different sizes are shown in Table 6. Considering the large firms' dominating role in S&T and their small share of the number of firms, it is not

surprising that their S&T intensity is much higher than for medium and small firms. For instance, around 74 percent of large firms conducted S&T in 2000. The corresponding figures for medium and small firms are 35 and 9 percent respectively. Interestingly, the share of firms with S&T has declined for all size categories between the two years, suggesting that the strong growth of Chinese industry is not primarily in S&T intensive activities. The other variables confirm a relatively high S&T intensity in large firms and most variables are relatively stable over these two years. It is particularly interesting to note that large firms totally dominate the launch of new products, for domestic sales as well as for exports.

Table 6 about here

6. WHAT CHARACTERIZE SMALL S&T- BASED FIRMS?

The above analysis suggests that small firms play a minor role in the overall Chinese S&T development. It should be pointed out that successful small firms will most likely grow out of the small size category and the figures might therefore in some sense underestimate their contribution to S&T development. Moreover, aggregate figures shown in the previous tables might blur the importance of small S&T firms since most small firms are obviously not engaged in S&T. To get a better understanding of small S&T firms, we include Table 7 where small firms with S&T are compared with small firms without S&T as well as with large- and medium- sized firms with S&T. Some conclusions can be drawn from the comparison.

General economic indicators and S&T by firm size

Table 7 shows that the number of firms has increased in all different categories. The vast majority of new firms are small without S&T. This group has increased with 35 percent over the period.

The growth has been even higher for small firms with S&T, almost 50 percent, albeit from a low starting point. The number of medium and large sized firms increased by 15 and 35 percent respectively.

The growth in the number of firms is not matched by a similar uniform increase in employment over firm categories. Job growth has mainly taken place in small firms without S&T. Employment in other categories has either declined (small and medium sized firms with S&T) or increased marginally (large firms with S&T). This means that job creation takes place mainly in small and low-tech firms, which might be an expected development but one that is not in line with Chinese current policies.

Moreover, it is seen that small firms with S&T have higher labor productivity than small firms without S&T. Large firms with S&T have the highest productivity level. This could be caused by superior technology, but also by relatively high capital intensity: small firms with S&T are more capital intensive than small firms without S&T, and the larger the firm the higher the capital intensity. Despite relatively high productivity and capital intensities in small firms with S&T, the export to sales ratio is lower than in small firms without S&T.

The above comparison shows that neither exports by small firms nor jobs created in small firms in China are S&T intensive, but probably based on labor intensive manufacturing. This contrasts the previously discussed result on European countries where S&T intensive small firms tend to show a relatively high level of outward orientation.

The comparison of S&T indicators by firm size shows some other interesting differences between small firms and LMEs. Besides a general increase in S&T- and R&D intensities across all firm sizes, small firms have high S&T input intensities compared to LMEs. Second, small firms have higher S&T intensities not only in terms of physical inputs, but also for human resources: the skill intensities, measured by S&T personnel to total employment ratio and R&D

personnel to total employment ratio, are higher in small firms than in LMEs. Third, in terms of S&T output, measured by patents per 100 employees, small firms outperform LMEs in both patent applications and patents granted. This is in line with most previous studies on other countries, which typically find a negative relation between firm size and R&D productivity.[5] On the other hand, the ratio of new products to total sales is lower in small firms than in LMEs. One reason could be that some small firms specialize in production and sales of technologies rather than in using the technology in their own production (e.g. Hicks and Hegde, 2005).

Despite relatively high levels of both S&T inputs and outputs, small firms seem to experience more difficulties in their internationalization process. Small firms have low technology import to sales ratio, and export to sales ratio, in comparison to LMEs. Small firms thus have less access to foreign technology and international markets, which can be due to both technological and institutional reasons. One obvious example is the previously discussed problem for small firms to be allowed to export.

Table 7 about here

S&T by firm size and by industry

One may ask if the relatively high S&T intensity of small firms can be caused by industry-specific factors. In other words, large and small firms might be distributed differently over sectors which could explain the above results if small firms tend to be located in high-tech industries. To control for such a possibility, we compare in Table 8 a few of the key S&T input- and output indicators across both firm size and by industry for 2004. The industries selected are the most S&T intensive ones in Chinese manufacturing.

[5] See for instance Acs and Audretsch (1990, 1991), Graves and Langowiz (1993), and Cohen and Klepper (1996).

The figures seem to support previous results: R&D to sales ratios are higher in small firms than in LMEs in most industries. The exceptions are textile, non-metallic mineral products and electrical machinery and apparatus. Accordingly, small firms have a higher relative S&T output: the number of patents per 100 employees is larger in small firms in all industries except electrical machinery and apparatus. Hence, the previously found high S&T intensities in small firms with S&T is not a result of a difference in the distribution over sectors between firms of different sizes.

It is also worth noting that the less advantageous access to foreign technology and markets of small firms is seen across most investigated industries. This can be observed in terms of both technology import and new product export. Another interesting point to note is the similar pattern in new product export between large and small firms. Large firms have the highest new product export to sale ratios in textile, electronic machinery and computer and telecommunication, which is also where small firms have a relatively strong performance.

Table 8 about here

S&T by firm size and by ownership

Another possibility is that firms of different sizes tend to have different ownership and that it is ownership rather than size that explains S&T. To control for this possibility, we compare S&T indicators across ownership groups in Table 9. Once again, the ratio of R&D to sales in small firms are higher than in LMEs in most ownership groups, except in collective firms and joint ventures with firms from Hong Kong, Taiwan and Macao. Regarding patent output, small firms also outperform LMEs in most ownership groups.

There are two other interesting observations worth mentioning. First, among small firms, wholly foreign-owned firms have (much) higher patents per 100 employee ratios than foreign

joint ventures. This is what one could expect if foreign firms require full control of their investment to bring in or develop relatively sophisticated technologies. Surprisingly, the same pattern is not found in other size categories. Second, domestic private firms have shown a strong patent performance in all firm sizes. Finally, joint ventures seem to have better access to both foreign technology and markets compared to their counterparts with other types of ownership, and it is true for both small firms and LMEs.

Table 9 about here

7. CONCLUDING REMARKS

Science and Technology receives a large interest from Chinese policymakers. Moreover, the growth in various S&T indicators over the last few years has been impressive. However, this growth has started from a low level and has also been accompanied by a high growth in all types of economic indicators. As a result, the increase in S&T intensities has been far less than the growth in absolute S&T efforts.

Small firms can be important in countries' technological development, as witnessed by the experience in a diverse range of countries. The situation in China has been largely unknown due to lack of information on small firms' engagement in technology activities. This has been a major drawback in the previous attempts to evaluate the S&T situation in China, considering that small firms constitute an overwhelming share of the total number of Chinese firms, and that small firms with S&T account for roughly two thirds of all firms engaged in S&T.

This paper has made a detailed mapping of S&T in small Chinese firms. One conclusion is that the role of small firms in Chinese S&T is rather similar to the situation in many other countries. For instance, it is seen that S&T in small firms constitute a minor share of total S&T.

S&T shows a large concentration in large Chinese firms, larger than the concentration for most other economic indicators, such as output, employment and export.

However, it would be premature to conclude that small firms are unimportant in the overall Chinese S&T development. In a sub-sample of small firms with S&T, it is found that S&T indicators on inputs as well as outputs tend to be higher than in large- and medium- sized firms with S&T. Again, a result that is similar to what has previously been found in some other countries. This suggests that small firms can be important in Chinese technology development and that some of these firms might be sufficiently successful in their S&T development to make them expand and eventually join the group of large sized Chinese firms.

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Table 1. Classification of Large, Medium and Small Enterprises

	Large (1)	Medium (2)	Small (3)
Employment (Person)	2000+	300-2000	300-
Turnover (Million Yuan)	300+	30-300	30-
Fixed assets (Million Yuan)	400+	40-400	40-

Source: National Bureau of Statistics of China .

Notes: Firms with a minimum turnover of 5 million Yuan are included in the sample of the economic census of China. The classification of firm size is made according to the above combined indictors. Firms are classified as large if all three criteria in column (1) are satisfied. The remaining firms are classified as medium if all three lower bounds in column (2) are satisfied. Otherwise they are classified as small.

Table 2. S&T in Chinese Manufacturing

	2000	2004	Growth 2000-2004 (%)
S&T expenditure	101	240	138
R&D expenditure	41	111	170
Technological renovation	122	295	142
Import of technology	28.2	39.7	41
Technology absorption	2.0	6.1	205
Domestic technology	3.0	8.2	173
S&T personnel (1000 Head counts)	1669	1839	10
With formal qualifications	631	635	1
Without formal qualifications	309	430	39
R&D personnel (1000 FTE)	630	814	29
Patent Application (Piece)	19850	64577	225
Invention patent application	5564	20458	268
Invention patent granted	10949	30343	177
New product sales	884	2280	158
New product exports	163	531	225

Source: National Bureau of Statistics of China.

Note: Nominal terms are in billion Yuan. R&D personnel are measured as Full–Time Equivalent (FTE), whereas the other types of S&T personnel are measured by headcount.

Table 3. S&T Characteristics in Chinese Manufacturing (%)

	2000	2004
Share of firms with S&T	11.9	14.8
S&T expenditures/Sales	1.20	1.21
R&D expenditures/Sales	0.49	0.56
Technological renovation/Sales	1.45	1.48
Import of technology/Sales	0.34	0.20
Technology absorption/Sales	0.02	0.03
Domestic technology/Sales	0.04	0.04
S&T personnel/total employment	3.00	2.78
With formal qualifications/Total employment	1.14	0.96
Without formal qualifications/Total employment	0.56	0.65
R&D personnel/Total employment	1.13	1.23
Patent application/ 100 Employee	0.04	0.10
Invention Patent Application/ 100 Employee	0.01	0.03
Invention patent granted/ 100 employee	0.02	0.05
New product sales /Sales	10.5	11.47
New product exports/Sales	1.94	2.67

Source: National Bureau of Statistics of China .

Table 4. R&D intensity in high-tech industries (%)

	R&D/value-added 2001	R&D/ value-added 2003	R&D/value-added U.S. (2001)	R&D/value-added Japan (2001)
Manufacturing average	3.4	2.0	8.7	9.9
High-tech average	5.0	4.4	27.2	26.3
Areospace	15.0	15.8	14.4	22.3
Pharmaceutical products	2.6	2.7	14.8	22.9
Computers and office machines	4.1	2.5	36.7	30.7
Electronic, telecommunications	5.8	5.4	37.2	18.6
Medical equipments and Meters	2.5	3.0	36.8	30.2

Source: National Bureau of Statistics of China and China Statistics Yearbook on high technology industries, 2004 & 2005.

Table 5. S&T by firm size in Chinese industry (%).

	2000			2004		
	Large	Medium	Small	Large	Medium	Small
Share of firms	0.9	10.9	88.3	0.8	9.2	90.0
Share of sales	33.2	35.3	31.6	35.7	31.6	32.7
Share of value added	31.3	34.9	33.8	34.4	31.7	33.9
Share of employment	21.5	34.5	44.0	20.8	32.2	47.0
Share of capital stock	44.5	39.6	15.9	39.5	34.0	26.5
Share of export	21.8	43.7	34.6	32.8	38.0	29.2
S&T expenditures	43.9	38.1	18.0	50.6	32.7	16.7
R&D expenditures	49.1	35.3	15.5	55.8	30.6	13.6
Technological renovation	58.3	32.7	9.0	62.9	24.7	12.4
Import of technology	47.6	39.1	13.3	62.5	30.1	7.4
Technology absorption	59.6	29.1	11.3	54.4	33.8	11.8
Domestic technology	32.6	47.0	20.4	55.1	29.7	15.2
S&T Personnel	38.6	40.5	20.9	43.6	35.3	21.1
With formal qualifications	43.0	37.2	19.9	48.6	32.5	18.9
Without formal qualifications	38.3	38.4	23.3	41.1	35.1	23.8
R&D Personnel	40.6	40.6	18.8	46.8	33.8	19.4
Patent Application	28.6	37.7	33.6	32.2	33.4	34.5
Invention patent application	25.7	32.9	41.4	40.5	27.5	32.0
Invention patent granted	27.4	39.6	33.0	23.7	35.7	40.6
New product sales	55.4	35.4	9.2	60.2	29.3	10.5
New product exports	41.5	50.1	8.4	59.7	31.7	8.6

Source: National Bureau of Statistics of China .

Table 6. S&T Intensities in Chinese manufacturing Firms (%)

	2000	2004	2000	2004	2000	2004
	Large	Large	Medium	Medium	Small	Small
Share of firms with S&T	82.7	74.5	44.3	35.3	10.5	9.0
S&T expenditures/Sales	1.6	1.7	1.3	1.2	0.7	0.6
R&D expenditures/Sales	0.7	0.9	0.5	0.5	0.2	0.2
Patent application/ 100 Employee	0.0	0.2	0.0	0.1	0.0	0.1
S&T personnel/Total Employment	5.4	5.8	3.5	3.0	1.4	1.2
R&D personnel/Total Employment	2.1	2.8	1.3	1.3	0.5	0.5
Import of technology/Sales	0.5	0.3	0.4	0.2	0.1	0.0
New product sales /Sales	18.4	20.0	10.7	10.7	2.9	3.6
New product exports/Sales	2.5	4.6	2.8	2.7	0.5	0.7

Source: National Bureau of Statistics of China .

Table 7. Firm characteristics by firm size and S&T status

	Small firms Without S&T		Small firms With S&T		Medium firms With S&T		Large firms With S&T	
	2000	2004	2000	2004	2000	2004	2000	2004
Number of firms	128660	226506	15125	22307	7832	9034	1180	1592
Employment (1000 head counts)	20657	27810	3794	3345	9836	8019	10408	11418
Value added (1000 Yuan)/Employee	31.1	204.9	40.9	296.8	47.0	345.6	74.0	503.2
Fixed assets (1000 Yuan) /Employee	54.2	65.1	68.8	90.8	104.5	140.4	155.2	242.5
Export /Sales (%)	19.0	18.2	13.8	14.9	16.6	20.2	10.2	15.5
S&T expenditure /Sales (%)	-	-	4.1	4.4	2.5	2.8	1.8	2.0
R&D expenditure /Sales (%)	-	-	1.4	1.6	1.0	1.2	0.8	1.0
Tech renovation/Sales (%)	-	-	2.1	2.0	2.5	2.1	2.9	3.0
Tech import/Sales (%)	-	-	0.6	0.2	0.7	0.3	0.5	0.4
Tech absorption/Sales (%)	-	-	0.1	0.1	0.0	0.1	0.0	0.1
Domestic tech/Sales (%)	-	-	0.1	0.1	0.1	0.1	0.0	0.1
S&T personnel /Total employment (%)	-	-	9.2	11.6	6.9	8.1	6.2	7.0
With formal qualification /Total employment		-	3.3	3.6	2.4	2.6	2.6	2.7
Without formal qualification/Total employment		-	1.9	3.1	1.2	1.9	1.1	1.5
R&D personnel/ 100 Employment	-	-	3.1	4.7	2.6	3.4	2.5	3.3
Patent application/100 Employee	-	-	0.2	0.6	0.1	0.3	0.1	0.2
Invention patent application/ 100 Employee	-	-	0.1	0.2	0.0	0.1	0.0	0.1
Invention patent granted /100 Employee	-	-	0.1	0.3	0.0	0.1	0.0	0.1
New product sales/Sales (%)	-	-	16.1	17.9	19.7	22.0	20.7	23.3
New product exports/Sales (%)	-	-	2.8	3.2	5.1	5.2	2.7	5.3

Source: National Bureau of Statistics of China .

Table 8. S&T intensity by firm size and sector in 2004 (%).

	Small firms with S&T				Medium sized firms with S&T				Large firms with S&T			
	R&D /Sales	New product Export /Sales	Tech imp. /Sales	Patent/ 100 Employ.	R&D /Sales	New Prod. Export /Sales	Tech import /Sales	Patent/ 100 Employ.	R&D /sales	New prod. export /Sales	Tech import /Sales	Patent/ 100 Employ.
Textile	1.00	8.64	0.17	0.41	1.27	7.97	0.26	0.08	1.21	12.24	1.21	0.04
Basic chemicals	1.44	3.57	0.14	0.47	1.42	3.11	0.12	0.20	1.12	0.73	0.86	0.08
Pharmaceuticals	2.42	2.96	0.09	0.50	1.76	2.31	0.41	0.31	1.51	5.27	0.18	0.31
Non-metallic mineral product	1.18	4.45	0.09	0.36	1.29	5.05	0.16	0.21	1.37	6.58	0.42	0.17
Machinery, general	1.91	3.14	0.20	0.53	1.82	6.06	0.37	0.29	1.71	5.29	0.57	0.18
Machinery, special	2.73	2.49	0.19	0.85	1.84	3.60	0.19	0.28	1.42	1.71	0.26	0.20
Transport equipment	1.93	2.19	0.94	0.43	1.29	4.66	0.39	0.28	1.69	3.24	0.86	0.29
Electrical machinery &apparatus	1.73	3.26	0.11	0.88	1.55	6.73	0.24	0.44	2.46	16.47	0.21	1.26
Computer, communication	3.37	6.59	0.26	0.79	1.45	12.31	0.86	0.50	1.99	23.16	0.44	0.71
Office machinery, measuring instruments	3.13	2.37	1.21	1.84	2.35	10.55	0.12	0.57	0.81	17.21	0.04	0.38

Source: National Bureau of Statistics of China .

Table 9. S&T intensity by firm size and ownership in 2004 (%).

	Small firms with S&T				Medium firms with S&T				Large firms with S&T			
	R&D /Sale	New prod. export /Sales	Tech imp. /Sale	Patent/ 100 Empl.	R&D /Sales	New prod. exp. /Sales	Tech import /Sales	Patent/ 100 Empl.	R&D /Sale	New prod. export /Sales	Tech imp. /Sales	Patent/ 100 Empl.
SOE	1.19	0.29	0.19	0.51	0.96	1.10	0.18	0.07	0.91	1.55	0.32	0.06
Collective	1.36	1.97	0.03	0.36	0.96	2.27	0.12	0.15	2.11	10.13	0.17	0.50
JV HTM	0.97	4.22	0.21	0.37	1.31	6.68	0.15	0.32	1.01	23.01	0.40	0.41
JV Foreign	1.64	4.22	0.64	0.42	1.24	10.88	0.90	0.48	1.30	6.44	1.18	0.74
Foreign	1.44	6.61	0.22	0.79	1.04	9.64	0.51	0.37	0.99	24.37	0.15	0.25
Shareholding	1.90	2.75	0.18	0.56	1.38	3.20	0.24	0.25	1.13	2.50	0.39	0.20
Private	1.55	3.21	0.13	0.66	1.23	5.70	0.10	0.40	0.74	5.90	0.05	0.90

Source: National Bureau of Statistics of China .