The Role of Small Firms in the Technology Development of China*

Fredrik Sjöholm and Nannan Lundin

ABSTRACT

Science & Technology (S&T) is high on the Chinese policy agenda and the country aims at becoming an innovation driven economy. Small firms have been important in technology development in other East Asian countries but the situation in Chinese small firms has been far less explored. We examine how much S&T 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 manufacturing firms in China in 2000 and 2004. Our results suggest that the role of small firms in Chinese S&T is similar to that 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.

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* FREDRIK SJÖHOLM is at the Research Institute of Industrial Economics in Stockholm, and at the Örebro University. NANNAN LUNDIN is at the Research Institute of Industrial Economics in Stockholm. We are grateful for support and help with the statistical calculations from Xiaojing Guan, He Ping and Jinchang Qian from the National Bureau of Statistics of China. We would also like to thank Sylvia Schwaag Serger and an anonymous referee for valuable comments on the paper. Nannan Lundin and Fredrik Sjöholm gratefully acknowledge financial support from the Wallander foundation and Torsten and Ragnar Söderberg's foundation, respectively.

1. INTRODUCTION

China is the second largest exporter in the world and the largest developing country recipient of foreign direct investments. Economic, political and technological changes in China are therefore likely to have large impacts on the global economy. Understanding global economic changes therefore requires an understanding of Chinese actual development and policy debates. Science & Technology (S&T) is currently very 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 to be the key driving force for sustainable economic growth and for a transformation of China into an innovation-oriented nation within the next 15 years (Chinese Ministry of Science & Technology, 2006).

The official rhetoric and emphasis on S&T seem 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 third largest performer of R&D in the world, just behind the U.S. and Japan and this has received a great deal of domestic and international attention (OECD, 2005a). 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 exceeded 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 about the actual S&T development in China. Previous studies tend to only focus on large and medium-sized enterprises (LMEs) and the situation in these enterprises is relatively well documented in statistical (e.g. National Bureau of Statistics, 2004) as well as in academic publications (e.g. Jefferson et al., 2003). To date, there is no comprehensive analysis of S&T activities in 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. Moreover, China is undergoing a rapid transition where the characteristics of small (private) firms are presumably of particular importance.

As a main contribution to the existing literature on S&T development in China, this paper aims at examining the role of small S&T-based firms. We try to deepen our understanding of the Chinese development by comparing it with experiences from other countries. 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. Moreover, we 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 the 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. This result also corresponds to what has been found in other countries. We also find small firms with S&T to have a higher productivity and capital intensity than other small firms but, perhaps unexpectedly, 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.

2. S&T ACTIVITIES IN SMALL FIRMS

a. Previous Studies

Theories on industrial evolution link small firms to economic growth through their roles in the 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 about future profits makes new firms enter the market on 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 about 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) construct 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 the economy.

Hence, there is 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 is a firm, the more likely it is to be engaged in innovation activities, such as R&D.[1] However, there is evidence, in particular among

[1] It should be noted that R&D might, in turn, affect the size of a firm. See Herrera and Lora (2005) for a study on determinants of firm size.

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.

How common are then small S&T based firms? Results for OECD countries show that about 30-60 percent of the small manufacturing firms 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.

Furthermore, 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 involved 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 might be 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 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 the exports in EU-15 member countries). However, the export capacity in these firms largely depends 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 a large-scale introduction of foreign technology, small high-tech firms have been the key driving force in the economic development of Taiwan. However, this central role of small firms might be about to change. There has been a steady increase in R&D expenditures by manufacturing small firms over the last decade, but their rate of growth has been slower than in large firms. The proportion of total R&D expenditures accounted for by small firms has therefore fallen, from above 35 percent in the 1990s to 28 percent in 2000 (Ministry of Economic Affairs, 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 there was a slight increase 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, exports and even outward direct investment. Their share of total business R&D has increased from 13 percent in 1995 to 27 percent in 2001 (Suh, 2004).

Moreover, while small Japanese firms are highly home-market oriented, small firms from Taiwan have traditionally been focused on foreign markets (La Croix, 2006). 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 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 favourable regulatory and investment framework, small firms tend to be more S&T-based.

b. The Chinese Context

The importance of small firms in China is closely associated with internal structural adjustment and intensified domestic and international competition. Since the mid 1990s, the large increase in small non-state-owned firms has not only changed the ownership structure of the Chinese industrial sector, but has also accelerated the privatization process 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 increase in capacity-building and competitiveness for small firms will have a strong impact on the industry as a whole. The labour market is also affected by the development of small firms since these are the main destination for workers laid-off from state-owned firms (SOEs) that re-enter the labour market. Finally, the urbanization process and enlarged higher education enrolment have increased the job creation pressure, even in the labour market for skilled labour, where small S&T-based firms can potentially absorb the rapidly increased human resources of S&T and provide a platform for entrepreneurship and innovation activities.

3. DATA DESCRIPTION

The data used in this paper is from the National Economic Consensuses and has been compiled by the 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 and 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 is balance sheets of firms from industrial statistics. The data structure in this dataset is very similar to the financial accounts of firms applied on a range of different countries in previous empirical studies. The other source is S&T statistics. Merging these two datasets and using unique firm identification codes, we obtain a dataset containing variables that 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 and 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, as shown in Table 1, is the latest updated version from 2004, where employment, turnover and fixed assets 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.

[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 less than a

After using the two datasets and applying the classifications described above, we are left with a sample of 162,892 firms in 2000 and 276,524 firms in 2004. The number of firms by size categories in 2000 is 143,785 small firms, 17,680 medium-sized firms and 1,427 large firms. The corresponding figures for 2004 are 248,814, 25,574 and 2,136.

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 two-digit level according to an industry classification, which is similar to the classification of ISIC, Rev. 3.

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

4. S&T IN CHINESE MANUFACTURING – AN OVERVIEW

The strong expansion of S&T in China is shown 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).

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given number of employees and are above certain financial thresholds. 250 employees constitute the upper limit in the European Union and 500 constitute the upper limit in the US. Moreover, the financial ceiling is defined at the level of 50 million Euro for medium-sized enterprises and 10 million Euro for small enterprises in the new EU standard classification.

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 technology, some of which 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 imports of technology or a purchase from other domestic actors, have also increased. Interestingly, there has only been a modest increase in imports of technology as compared to the high growth in other indicators. It is also worth pointing out that the expenditures on imports of technologies are substantially lower than the expenditures on own technological development, thereby suggesting that the often voiced concern of a dependence on imported technologies might be exaggerated. However, it should also be pointed out that this concern is often based on a correct observation of Chinese imports being more technology intensive than Chinese exports.

The number of S&T personnel has also increased, although at a lower rate than S&T expenditures. S&T personnel are divided into three categories: with or without formal qualifications (primarily education) and R&D personnel. The latter is the most skilled subgroup.[3] It is primarily R&D personnel or employees with little formal qualifications that have increased in numbers.

Table 2 about here

All 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 shown in the table, patent applications are

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

relatively few but there is a rapid increase, thus confirming previous results of the growth in patents in China between 2003 and 2005 being 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 of this measure are, first, that new products might materialize without any formal S&T and, second, that S&T might aim at improving already existing products or processes, rather than developing new ones. Bearing these caveats in mind, it is shown in Table 2 that there was a substantial increase in the sales and exports of new products over the period. It is also worth mentioning that most products are only sold on the domestic market.

To sum up the above discussion, it is seen that China is rapidly increasing its S&T activities. There are two different explanations with very different implications for this development. The first 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 by almost 10 percent annually, and where S&T is growing from low levels, the previously seen development might be natural and only what would be expected for a country like China. If this description is correct, the structure of the Chinese economy should largely remain unchanged. The second possible explanation is that these figures reflect a structural change of Chinese industry with an increased S&T intensity. One way of further examining this 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

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

percent. The implications are, first, that an overwhelming share of Chinese firms do not engage in any S&T and, second, 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 imports, renovation, efforts on absorption or domestic purchases, have also shown relatively small changes. The largest change is the decline in imports of technology, once more suggesting a slight decline in the dependence on foreign technologies. The last input measure shows a decline in the share of S&T personnel. However, this trend differs between different types of S&T personnel.

As previously mentioned, the number of patents is still relatively low in China but growing, and Table 3 shows there to be 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

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 only sold on the domestic market.

The conclusion from Table 3 is that there does not seem to have been any increase in the S&T intensity in Chinese industrial firms between 2000 and 2004. However, structural changes in the Chinese economy could explain the pattern observed in Table 3. For instance, if the relative importance of low-tech industries had increased during the period studied, the result would have been an overall stable S&T intensity even if the intensity were to increase in individual firms. One way of controlling for this possibility is to examine the issue at the 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 the average value added 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 high-tech industries in 2001 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 and that the success of these industries is rather the result of low costs and high integration with world markets (Adams et al., 2006).

Moreover, 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 the industrial transformation of countries. It might be asked 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 the Chinese firms are small and there has been a slight increase in this share 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 the value added and the 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 employment in the year 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: there is a small increase in firms' share of employment to around 47 percent and their share of the capital stock increased by a dramatic 10 percentage points to around 26 percent. Exports, finally, show an opposite trend where the share of large firms increases from 22 percent in 2000 to around 33 percent in 2004. Medium-sized firms still account for the largest share of exports.

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 only account 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). As compared to East Asian economies, the importance of S&T in small Chinese firms is similar to the experience in Japan and (previously) Korea, but it 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 to 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 of different technology sources. In other words, it seems to be the same group of firms that conducts own R&D, imports technology from abroad and purchases it from other domestic actors.

Employment shares once more show 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 the patent applications, which resembles the distribution of sales and value added across different size categories. This suggests that R&D productivity, as measured by the number of patents 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 the new products sold on the domestic market or as exports. 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. The differences between medium-sized firms and small firms, and between large firms and small firms, are statistically significant (at the 10 percent level) for all included variables. Considering the dominating role of large firms in S&T and their small share of the total 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 the 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, thereby suggesting that the strong growth of Chinese industry is not primarily in S&T intensive activities. The other variables confirm a 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 CHARACTERIZES 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, the 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 to small firms without S&T as well as to large- and medium-sized firms with S&T. Some conclusions can be drawn from the comparison.

a. 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 by 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 there has been a marginal increase (large firms with S&T). This means that job creation mainly takes place 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 labour productivity than small firms without S&T. Large firms with S&T have the highest productivity level but the difference as compared to small firms with S&T is not statistically significant. Despite relatively high productivity and capital intensities in small firms with S&T, the exports to sales ratio is lower than in small firms without S&T but, once more, the difference is not statistically significant.

The above comparison shows that neither exports by small firms nor jobs created in small firms in China are S&T intensive, but they are probably based on labour intensive manufacturing. This is in contrast to 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 as 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 the S&T personnel to total employment ratio and the 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 a low technology import to sales ratio, and a low exports to sales ratio, as compared to LMEs. Thus, small firms have less access to foreign technology and international markets, which can be for both technological and institutional reasons. One obvious example is the problem for small firms in being allowed to export.

Table 7 about here

b. S&T by firm size and by industry

It may be asked whether the relatively high S&T intensity of small firms can be due to industry-specific factors. In other words, large and small firms might be differently distributed 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 a few of the key S&T input- and output indicators across both firm size and by industry for 2004 in Table 8. The selected industries are the most S&T intensive in Chinese manufacturing.

The figures seem to support previous results: the 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

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

firms with S&T is not a result of the 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 imports and new product exports. Another interesting point to note is the similar pattern in new product exports between large and small firms. Large firms have the highest new product exports 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

c. S&T by firm size and ownership

Another possibility is that firms of different sizes tend to have different kinds of 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 more, the ratio of R&D to sales in small firms is 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.

Two other interesting observations are 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 could be expected 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 as compared to their counterparts with other types of ownership, and this is true for both small firms and LMEs.

Table 9 about here

7. SUMMARY CONCLUDING DISCUSSION

There is a large interest in Science and Technology (S&T) from Chinese policymakers. Moreover, the growth in various S&T indicators over the last few years has been impressive. However, this growth started from a low level and has also been accompanied by 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 the technological development of countries, as witnessed by the experience in a large range of countries. The situation in China has largely remained unknown due to lack of information about small firms' involvement in technology activities. This has been a major drawback in 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 involved 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 shown that S&T in small firms constitutes 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 exports.

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 the

S&T indicators on inputs as well as outputs tend to be higher than in large- and medium-sized firms with S&T. Once more, this is 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.

Considering that small firms are particularly important in a transition economy, such as the Chinese economy, and that the government is determined to increase the degree of technological sophistication in industrial production, it may be asked how small firms are best supported. The economic environment for entrepreneurship is generally considered to be good in China (OECD, 2007, p. 92). However, Huang et al. (2004, p.377) suggest that as compared 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. The literature offers some policy suggestions on how to support SMEs that often separate between macro policies, mainstream policies that influence SMEs, and policies at a micro level which are more directly targeted towards SMEs (OECD, 2007).

Macroeconomic policies typically highlight institutional aspects such as taxes, education and the legal framework (Henrekson, 2007; Henrekson and Johansson, 2009). One institutional aspect that is often stressed as important for the growth of technology-intensive SMEs is well defined property rights. This is an area which is clearly of relevance in China where the implementation of property rights is very rudimentary. The lack of property rights has presumably benefited China's ability to reverse engineering and other forms of technology absorption. However, it will not benefit firms trying to develop technologies of their own. There are signs of an increased awareness of the problem among policy makers, but there is a long way to go before new laws and regulations are actually implemented.

Another economic feature of China that is presumably having negative effects on the growth of SMEs is the domination of the financial sector by state-owned banks. Roughly 60 percent of the loans of these banks are to state-owned companies, which makes it difficult to raise capital for private companies in general and for SMEs in particular. *The Small and Medium-sized Enterprise Promotion Law* was adopted in 2003, which aims at improving these firms' access to bank lending and the credit guarantee system (INNOFUND, 2003). Despite some progress, the current financial market with few financing channels and lacking small- and non-governmental banks creates huge difficulties for small firms in China to fund their S&T activities (Wang, 2004). The Chinese financial sector is being liberalized but at a slow pace and a more rapid introduction of private foreign and domestic banks would, presumably, benefit private-sector development, including the growth of technology-intensive SMEs.

However, it should be noted that SMEs often have difficulties in getting access to capital even in countries with more developed financial markets. This brings us to microeconomic policies towards SMEs which often focus on providing capital, sometimes at a subsidised interest rate. The literature seems to give a mixed picture of the effectiveness of such policies. For instance, positive effects have been found in Canada (Riding and Haines, 2001) but no such effects have been found in Japan (Nitani and Riding, 2005). It is worth stressing that the evaluations of such programs have only been conducted in developed countries. There are reasons to believe that institutional constraints make the provision of subsidized capital more difficult to implement in a developing country such as China.

The same difficulties might be present but perhaps to a lesser extent for other types of government assistance programs, such as export promotion programs, marketing advice and other types of assistance to SMEs. Some of these policies are currently being implemented in China under the *Small and Medium-sized Enterprise Promotion Law*, where the focus seems to be on consulting support, technical innovation, market exploration and social services. The general experience of such programs in other (developed) countries is that they tend to have relatively modest effects on SME growth, and the expectations should possibly not be so high on the effect of such programs in China (see e.g. Wren and Storey, 2002; Lambrecht and Pirnay, 2005).

A relatively straightforward policy that would presumably favor SMEs is to liberalize the trade regime. Small firms are currently prevented from entering the international market, as most of them are not authorized to engage in imports and exports (Chen, 2004).

A final policy that might be tried is to encourage collaborations between universities and SMEs, for instance through the establishment of so-called science parks. However, the international experience of this type of policy is, once more, mixed, with some positive effects from such collaboration found in Greece (Bakouras et al., 2002) but with little visible effects in Sweden (Lindelof and Loftsen, 2003). There are some attempts in China to encourage new start-ups through e.g. high-technology incubators and S&T parks but no general evaluation on how effective these attempts have been.

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Table 1. Classification of Large, Medium and Small Enterprises

	Large (1)	Medium (2)	Small (3)
Employment (Person)	2,000+	300-2,000	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 (per cent)
S&T expenditure	101	240	138
R&D expenditure	41	111	170
Technological renovation	122	295	142
Imports 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)	1,669	1,839	10
With formal qualifications	631	635	1
Without formal qualifications	309	430	39
R&D personnel (1000 FTE)	630	814	29
Patent Application (Piece)	19,850	64,577	225
Invention patent application	5,564	20,458	268
Invention patent granted	10,949	30,343	177
New product sales	884	2,280	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 (per cent)

	2000	2004	Difference 2004-2000 t-value
Share of firms with S&T	11.9	14.8	-
S&T expenditures/Sales	1.20	1.21	1.13
R&D expenditures/Sales	0.49	0.56	0.05
Technological renovation/Sales	1.45	1.48	2.76***
Import of technology/Sales	0.34	0.20	4.93***
Technology absorption/Sales	0.02	0.03	1.46
Domestic technology/Sales	0.04	0.04	0.66
S&T personnel/total employment	3.00	2.78	3.03***
With formal qualifications/Total employment	1.14	0.96	8.38***
Without formal qualifications/Total employment	0.56	0.65	3.13***
R&D personnel/Total employment	1.13	1.23	5.80***
Patent application/ 100 Employee	0.04	0.10	12.84***
Invention Patent Application/ 100 Employee	0.01	0.03	9.46***
Invention patent granted/ 100 employee	0.02	0.05	11.15***
New product sales /Sales	10.5	11.47	5.10***
New product exports/Sales	1.94	2.67	11.54***

Source: National Bureau of Statistics of China.

Note: *Significant at the 10 per cent level; ** Significant at the 5 per cent level; *** Significant at the 1 per cent level.

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

	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 (2004; 2005).

Table 5. S&T by firm size category in the Chinese industry (per cent of total)

	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 (per cent)

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

Source: National Bureau of Statistics of China.

Note: The differences between medium-sized firms and small firms, and between large firms and small firms, are statistically significant (10 percent level) for all included variables.

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	128,660	226,506	15,125	22,307	7,832	9,034	1,180	1,592
Employment (1000 head counts)	20,657	27,810	3,794	3,345	9,836	8,019	10,408	11,418
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 (per cent)	19.0	18.2	13.8	14.9	16.6	20.2	10.2	15.5
S&T expenditure /Sales (per cent)	-	-	4.1	4.4	2.5	2.8	1.8	2.0
R&D expenditure /Sales (per cent)	-	-	1.4	1.6	1.0	1.2	0.8	1.0
Tech renovation/Sales (per cent)	-	-	2.1	2.0	2.5	2.1	2.9	3.0
Tech import/Sales (per cent)	-	-	0.6	0.2	0.7	0.3	0.5	0.4
Tech absorption/Sales (per cent)	-	-	0.1	0.1	0.0	0.1	0.0	0.1
Domestic tech/Sales (per cent)	-	-	0.1	0.1	0.1	0.1	0.0	0.1
S&T personnel /Total employment (per cent)	-	-	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 (per cent)	-	-	16.1	17.9	19.7	22.0	20.7	23.3
New product exports/Sales (per cent)	-	-	2.8	3.2	5.1	5.2	2.7	5.3

Source: National Bureau of Statistics of China.

Note: The differences between small firms with S&T and the other firms are statistically significant (10 per cent level) for all included variables with the following exceptions: exports in 2000 and 2004; value added and fixed assets in 2000 (medium and large); technological absorption in 2000 (large).

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

	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 (per cent)

	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.