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Do Manufacturing Firms in China Innovate?

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ABSTRACT *This article provides empirical light on the debate concerning whether manufacturing firms in China are becoming major innovators. Based on an innovation survey carried out in Jiangsu Province, the article finds that most firms engage in innovative activities but these are mainly of an incremental nature. Radical innovation, as a proportion of sales, is relatively low if compared internationally. Innovation in China is mainly to catch-up and is novel relative to the firm and the domestic market. A small proportion of innovation is new to the world. Intensity and productivity indicators suggest that small, foreign and textile firms are leading innovative efforts. Firms innovate to improve their general competitiveness, including improving product quality and extending market share, obtain income from technology and defend themselves from research and development expenditure by competitors. Innovators value significantly more than non-innovators the range of innovative objectives they seek to achieve. The main obstacles to innovation arise from technical and marketing weaknesses; the perception of these obstacles varies widely between radical innovators and non-innovators. The article concludes that while innovative activities are emerging it will still take some time for China to have a major role in the international division of innovative labour.*

KEY WORDS: Innovation, innovation indicators, innovation objectives, innovation obstacles, manufacturing industry, China

China's economic achievements since launching its market-orientated economic reforms in the late 1970s have been impressive. Not that rapid growth and acute structural change was unheard of in the country, but the pace at which economic transformations have been taking place for the last 20 years or so is staggering. Between 1990 and 2002 China's per capita growth doubled that of other "high performing" Asian economies, such as Singapore, South Korea and Hong Kong and there was a 10% hike in the share of manufacturing industry to 51.7% of GDP, making China one of the major sources of industrial goods in the world (see Schaaper, 2004). According to the Organisation for Economic Co-operation and Development (OECD) definitions, China's high-tech industry is as large as the European Union's and, taking into consideration its medium-tech industry as well, it

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is larger than the USA's, Japan's or Korea's. High-tech manufacturing exports (mainly consumer electronics and computer equipment) now account for the largest share of Chinese and 5% of world exports, increased seven-fold between 1992 and 2001 to $US67 billion and are more than half of the equivalent Japanese figure and more than a quarter of the USA's high tech exports (Schaaper, 2004).

While it is difficult to play down the importance of these achievements in terms of their impact on local development, some argue that China's high-tech exports are dominated by commodity or mature types of information technology products and therefore compete internationally on the basis of low wages, deteriorating margins and the importation of higher value-added components, which has also resulted in a deteriorating trade balance in high-tech products (Schaaper, 2004; Steinfeld, 2004). Rosen (2003) also pointed out that the Chinese are a long way from leapfrogging Western competitors in technology and innovation. China has yet to exhaust its labour endowment potential before moving to higher knowledge- and capital-intensive products, patents per capita still remain small, there are few financial options for innovative private firms and local firms have not been able to build reliable brand-name businesses. Further, what little innovation emerges takes place among foreign investors, who are the only ones with the required technical and managerial capabilities (Rosen, 2003).

Contrasting with this rather pessimistic view, there are some authors arguing that Chinese industry may be on the verge of a major technological transformation. Fischer and von Zedtwitz (2004), summarising these views, pointed out that the size of China's market, the large pool of foreign-trained and attractively priced scientists and engineers and growing local investment in research and development (R&D) will – if it hasn't already – attract not only foreign investors but also local firms into the creation of advanced technologies and innovation. Hu and Jefferson (2004) argued that provided China maintains its current growth rate and continues its international involvement, it should be able to continue its technological development. Sigurdson (2004) suggested that China may become, in the not too distant future, a "technological superpower."

The purpose of this article is to throw some empirical light on to this emerging debate. While much is beginning to be known at the macro-level, there is little understanding of the efforts by firms in China to develop advanced technologies and to innovate at the micro-level. On the basis of a local survey of firms, we will attempt to adress the questions: to what extent is innovation taking place?; what is innovated and by whom, both in technical terms and degree of novelty terms?; and why do firms innovate and what problems do they face in innovating? Given the size of the Chinese economy the study was concentrated on Jiangsu Province.

Jiangsu Province is an important location of manufacturing activity and a large recipient of investment in science and technology in China. It is located in the Yangtze River Delta, one of the three major concentrations of economic activity in China, and borders with Shanghai. It has a territory of 102,600 km^2 and 74.1 million people. Industry sales amounted to Yuan 1,353.2 billion ($US163.2 billion) in 2002 and there were 21,476 registered industrial enterprises (Jiangsu Statistical Bureau [JSB], 2003). Jiangsu accounted for 12.5% of total Chinese industrial output in 2002, a more than twenty-fold increase in real terms since the end of 1977, and was the second largest industrial producer nationally after Guandong Province

(National Bureau of Statistics of China [NBS], 2003). The main activities are textiles and garments, chemicals, electrical and electronics products and equipment and machinery. In 2002, current and capital expenditure on science and technology amounted to Yuan 29.6 billion, while R&D expenditure accounted for 1.8% of the province's GDP, 40% higher than the national average (JSB, 2003). The region boasts 295,200 individuals involved in scientific and technological tasks (JSB, 2003).

In the second section of the article the sources, definitions and characteristics of the survey undertaken in Jiangsu Province are presented. Section 3 will discuss the extent and pattern of manufacturing firm innovation in terms of the technical and extent of novelty dimensions of innovation as well as the objectives and obstacles underlying such innovations. To enable a better appraisal, the section will examine the behaviour of firms in terms of size, ownership and industry. The article will end with some conclusions on whether firms in China are, or will be, an innovation powerhouse.

The Jiangsu Province Innovation Survey (JPIS)

Definitions and Design

The questionnaire was designed following OECD and European Commission (EC) guidelines for innovation surveys, commonly known as the Oslo Manual (OECD/EC, 1997). Taking the cue from these guidelines, innovation was defined as the commercial introduction of new products and processes and the focus was the firm rather than the innovations themeselves.

However, certain modifications were introduced in the questionnaire design. The first change referred to the coverage of non-innovators and innovation types, as the JPIS questionnaire includes non-innovators and technological innovations and makes a distinction between product and processs innovations. The second modification related to broadening the technical definition of innovation to include both radical and incremental innovation. Significant or radical product innovation involves a transformed design, profound changes in the technical characteristics and features, alternative inputs or components and/or creating different uses or applications for a good. Significant or radical process innovation involves modifications in the layout of production or a completely new production line; the use of different facilities, equipment and/or machinery; and, changes in the way inputs and resources are used and deployed. Incremental product innovation involves adaptation, enhancement or upgrading in design, technical characteristics, use of inputs and components and applications of the good. Incremental process innovation requires adaptation, enhancement or upgrading in the layout, methods, resources and use of inputs of production. From a technical perspective incremental innovation is far less sophisticated than radical innovation and hence requires less advanced scientific and technological knowledge. The third major modification aimed at getting an even better sense of the degree of novelty. The Oslo Manual distinguishes between two extremes, innovation new to the world, as the highest degree of novelty, and innovation new to the firm, as the lowest degree (OECD/EC, 1997). When a product or process is new to the world it can unquestionably be considered as innovation and its degree of novelty is the highest achievable as no individual, firm or market has ever been exposed to it. Given the large size of China's economy and of its individual provinces, innovation novelty was defined in terms of intermediate degrees, as new to the country and new to the province: China and Jiangsu. Jiangsu Province innovations refer to the introduction of products and processes already available elsewhere in China. Often they involve imitation but require an additional local marketing effort at providing some product information, as a limited amount is already available, and at identifying distribution channels. There may be some adaptations to local tastes that need to be communicated to potential customers. Provincial markets in China are large, idiosyncratic and, until not too long ago, self-reliant, so it makes analytical and commercial sense to deal with them separately. Innovations for the Chinese market include both imitations from abroad not seen locally before, and totally new products and processes developed exclusively for the national market. They require significant marketing efforts in providing information and opening the necessary marketing channels given the size and growing complexity of the Chinese economy. The fourth modification involved limiting the reference period to one year (2002), unlike the three-year period used in some surveys.

Application

The survey covered manufacturing firms only. The statistical units were firms of ten or more employees. The original version of the questionnaire was in English, then translated into Chinese, and finally checked against the original English version to ensure fidelity. Chief Executive Officers (CEOs), R&D managers and/or senior corporate managers filled in the questionnaires.

Jiangsu Province had 18,309 industrial firms in 2000, the year on which the initial estimates were based (JSB, 2001). After excluding non-manufacturing and rural firms it was estimated that in the capitals of the province's 13 municipal counties there would be around 12,000 manufacturing firms. An initial selection was made by using every fifth firm from the county capital's telephone directory as there was no official registry of firms available.

After pilot testing the questionnaire with Jiangsu Province Statistics Department officials and a few managers, questionnaires were distributed to around 2500 manufacturing firms, between May and October 2003, yielding 360 returns. A 3% sample of the enterprises population was believed would provide a reasonable description of the province's urban manufacturing effort. After eliminating duplications and non-manufacturing firms, there were 354 potentially usable questionnaires, accounting for around 9% of total manufacturing sales in the province.

Manufacturing Innovation in Jiangsu Province

The Extent of Innovation

The JPIS showed that 91.3% of surveyed firms answering the question of whether they had introduced innovation indicated they had done so, of which 80.3% claimed they had introduced product and process innovations, 12.9% product innovation only and 6.8% process innovation only. Firms that claimed they had introduced product innovation amounted to 85.5%, while firms claiming introducing process innovation amounted to 79.9%.

At first sight these results seem exceedingly high. Although there had been considerable dynamism and competition for some time among Jiangsu firms, which should translate into companies continuously trying to modify and improve their products and manufacturing processes to cater for increasing domestic and foreign demand, the sheer share of innovative firms in total firms was, none the less, startling. In Canada's 1997-99 innovation survey, which shows the highest-ever recorded innovation figures for all developed countries, 80.2% of manufacturing firms were innovators (66.7% product and process, 18% product only and 15.3% process only), while 68% introduced product innovations and 65.8% introduced process innovations (Statistics Canada, 2002). The EU's Community Innovation Survey (CIS3) for 1998-2000 showed 44% of manufacturing firms engaged in some innovative activity (59.1% product and process, 22.7% product only and 18.2% process only) while between 2001 and 2003 in other developed countries, such as Australia, 39.5% of manufacturing firms innovated, while 27.1% introduced product innovation and 29.7% introduced process innovation (Australian Bureau of Statistics [ABS], 2006; EC, 2004). Within individual countries, the share of innovative firms in total firms was 60% in Germany, 59% in Belgium, 51% in the Netherlands, 49% in Ireland, 44% in Finland, 41% in France, 38% in Italy, 37% in Spain and 32% in the UK.

Innovation surveys carried out in developing countries also show much lower figures. Argentina's 1998-2001 survey found that 56% of manufacturing firms innovated, while 46% of firms innovated in products and 47% in processes (INDEC, 2003). South Africa's 1998-2000 innovation survey revealed 49.9% of manufacturing firms engaging in innovation while, between 2000 and 2001, 35% of Malaysian manufacturing firms declared themselves as innovators (MASTIC, 2003; Oerlemans et al., 2003). In 2001-03, 33.3% of Brazilian manufacturing firms had some innovative activity, while 20.3% introduced product innovations and 26.9% introduced process innovations (IBGE, 2005). In Mexico, in 1999-2000, 28% of manufacturing firms were developing at least one innovative project, of which 44% were both product and process projects, 34% were product innovation projects only and 22% were process innovation projects only (CONACYT-INEGI, 2003).

When comparing international data one key factor to keep in mind is the voluntary or mandatory nature of the survey. In their comparison between the Canadian and European surveys, Therrien and Mohnen (2003: 362) argued that the legal status of the survey may introduce a selection bias into the results. In countries where the survey is voluntary, the proportion of innovative firms represented should be higher, as non-innovative firms will feel that the questions raised are not relevant for them and hence tend not to respond. In countries where the survey is obligatory both types of firms would be represented equally. Within European countries, the surveys in Ireland and Germany were voluntary while in France it was mandatory. The response was obligatory in the Brazilian case and was voluntary in the JPIS, the Australian and South African surveys.

A second factor to remember when comparing internationally has to do with differences in definition and coverage. In terms of definition, the Australian Innovation Survey, for instance, defines innovation including changes in organisational and managerial processes, while the Argentinean and South African surveys consider, in addition, changes in commercialisation practices. In terms of coverage, the Canadian Innovation Survey collects data from firms with revenues over $C250,000 and 20 or more employees, the Australian survey includes firms with more than five employees, the Mexican survey includes firms with 50 or more workers, and the JPIS, CIS3 and other surveys include firms with ten or more employees.

A third factor to consider in international comparisons relates to the level of sophistication of specific products. The same product manufactured in different countries or locations may involve different degrees of complexity in design, engineering, manufacturing process and use of raw materials and labour. This implies significantly different stages in the evolution of uderlying technology. The same product can be "state of the art" or incipient and, hence, at different moments of the S-diffusion curve, yet comparisons do not take this into account.[1]

In order to be able to assess the extent of innovation in China fully, it is also necessary to delve into the distinction radical/incremental, as the JPIS provides means of exploring this difference. Taking into account that "significant" in the Oslo Manual is equivalent to the JPIS concept of "radical," comparable Chinese figures with other country surveys showed 65.9% of manufacturing firms engaging in innovative activity (16.1% product only, 8.9% process only and 75% product and process), 58.5% of manufacturing firms engaging in product innovation and 54.2% engaging in process innovation. These figures still remain relatively high in international terms.

To appraise better the extent of innovation, the JPIS did not only ask questions as to whether firms had any innovative activity (yes/no) but also about the share of sales of unchanged and radical/incremental products and processes. Table 1 shows a majority of total sales from surveyed firms coming from existing products and processes. Furthermore, most of the innovation in China is incremental, something that is consistent with the literature on the nature of innovation in developing countries. Yet, the extent of radical innovation – what the Oslo Manual considers significant innovation – is noteworthy. Chinese product innovation sales account for 16.3% of total manufacturing sales, while process innovation sales account for 15.9% of total manufacturing sales. In 2000, product innovation share of manufacturing sales in Europe, the only comparable figures available, were 39.2% in Germany, 24.5% in Spain, 24.4% in Italy, 24.1% in the Netherlands, 22.4% in

Table 1. Share of old and new products and processes in total sales, all sampled firms (% and number of firms)

	Product %	Process %
Old	59.0	60.8
New	41.0	39.2
– of which, radical	39.8	40.6
Incremental	60.2	59.4
No. of firms	289	264

Source: Jiangsu Province Innovation Survey.

Finland, 17.6% in the UK, 15.7% in Belgium and 14.8% in France (EC, 2004). Sales arising from product innovation by Mexican firms also in 2000, amounted to 37% of total manufacturing sales (CONACYT-INEGI, 2003).

Table 2 provides an idea of the breakdown by degree of novelty. The largest share of product and process innovation sales in China is of the "catching-up" type. Innovations new to China account for a larger share of product and process sales than innovations new to Jiangsu Province. Most importantly, innovations new to the world account for the smallest proportion of product and process innovation sales. Product innovations new to the world included: biotechnology (long-lasting food oil and anaesthetics), electronics (digital controllers, printers, cameras, LCD screens and laptop computers), machinery (miniature electrical machinery, high-speed cutting tools and high-pressure valves), new materials (reactive ceramics and composite synthetic/natural fibres) and toys of different kinds. Process innovations new to the world included: heat process technologies, specialised conservation techniques for wine, new fermentation processes for pharmaceuticals and state-of-the-art grinding and surface treatment technologies in mechanical engineering.

What is Innovated and by Whom?

The Technical Magnitude of Innovation

To identify the technical magnitude of innovation, radical or incremental, in the Chinese economy, we have focused on three characteristics of the firms: size, ownership and industrial activity. The technical magnitude of innovation will be measured in terms of three indicators: *propensity* to or incidence of innovation (the proportion of firms with any innovation activity in the total number of firms from each group); *intensity* of innovation (a mean share of innovation sales in total sales for each group of firms); and *productivity* of innovation (a mean of innovation sales per worker for each group of firms, expressed as a relative percentage of the total). Propensity indicates whether there is innovation irrespective of the magnitude of the effort, while intensity provides some sense of importance by making a link with the share of sales of new products. Productivity attempts to control for size by dividing sales of new products by number of workers, although to make the index easily comparable the average sales/worker for a specific group has been made 100; hence, individual firms or groups of firms can be above or below 100. The propensity-intensity-productivity (PIP) indicators will be referred to innovators only.

Table 2. Share of product and process innovation by degree of novelty, all sampled firms (% and number of firms)

Degree of novelty	World	China	Jiangsu	Firm	Total	No. of firms
Type of innovation						
Product	4.0%	12.0%	7.4%	15.8%	39.2%	229
Process	5.1%	7.9%	6.6%	13.3%	32.9%	191

Source: Jiangsu Province Innovation Survey.

Size. China has no consistent definition of firm size. Liang (2003) and Jefferson et al. (2003) have pointed out that China uses a number of different size definitions which have changed several times and, since 1998, are industry specific and include a combination of fixed assets and production capacity. Liang (2003: 1) added that the Chinese government would also seem to use a cut-off figure of 500 employees to differentiate small and medium enterprises from larger ones. Given that the JPIS had information on employment and that most firm size classifications around the world still emphasise this dimension, it was decided to adopt an employment-based definition. To make the data comparable, a classification was introduced, which includes seven groupings commonly used in other countries.

The innovation literature is divided about the relationship between firm size and innovation (Stock et al., 2002). Some argue that because small firms are greater risk takers, flexible, communicative, focused and motivated, they can innovate far more than large firms (Acs and Audretsch, 1990). Others argue that, due to their larger resources and better access to finance, R&D scale economies, market power, developed marketing channels and internal capacity to diversify risk, large firms are generally more innovative than small firms (Cohen and Klepper; 1996; Schumpeter, 1942). Yet, some other authors contend that small firms focus on product innovation, while large firms focus on process innovation due to product life-cycle considerations (Abernathy and Utterback, 1978).

The JPIS data presented in Table 3 provide ammunition for all camps. The propensity to radical product and process innovation is, on the whole, higher among

Table 3. Radical and incremental innovation by firm size, innovators only (%)

No. of employees	10-49	50-249	250-500	501-1000	1001-2000	2001-5000	5001 or more	Total
Propensity								
Radical								
Product	70.0	67.2	75.5	75.0	52.2	78.9	75.0	70.2
Process	75.0	71.1	65.9	82.6	68.2	91.7	71.4	72.9
Incremental								
Product	80.0	93.1	95.9	82.1	91.3	94.7	75.0	90.2
Process	80.0	93.3	92.7	87.0	81.8	100.0	71.4	88.8
Intensity								
Radical								
Product	26.5	18.2	21.4	23.3	11.3	16.7	9.0	19.2
Process	26.7	21.0	20.0	26.5	16.3	17.9	20.4	21.3
Incremental								
Product	28.1	29.8	29.1	25.5	29.9	32.2	21.9	28.8
Process	33.1	32.9	28.1	28.5	23.0	44.0	32.4	30.7
Productivity								
Radical								
Product	306.6	37.5	153.8	101.4	32.4	41.9	20.4	100
Process	218.2	44.3	105.2	126.5	61.5	100.7	104.1	100
Incremental								
Product	32.6	43.9	266.6	60.8	48.9	55.4	45.3	100
Process	381.4	31.4	58.1	127.5	54.2	59.5	84.8	100

Source: Jiangsu Province Innovation Survey.

large firms, particularly among those employing 2001-5000 employees. The propensity to incremental innovation is distributed more evenly across size, with firms in the 250-500 employees group accounting for the highest product propensity and firms in the 2001-5000 employees class accounting for the highest process propensity. In terms of intensity the evidence is also mixed. Radical product and process innovation is more intense among small and medium firms, but incremental product and process innovation is marginally more intense among large firms. Productivity indicators are, however, slightly more clear cut. Small and medium firms' workers are more productive in all types of innovation, except for incremental product innovation, where firms in the 250-500 employees segment exhibit higher productivity levels. Altogether, the data also provide some support to product life-cycle views as small and medium firms are relatively stronger at product innovation, while large firms tend to emphasise more process innovation.

Examining the data from an international perspective provides additional insights. Table 4 shows the product innovation PIP indicators for a number of countries that had comparable data. In the Continental European countries shown, there is a clear pattern of all PIP indicators growing as size increases. The pattern is somewhat mixed in the case of the UK, where propensity and productivity are highest in small firms but the intensity increases with size. Data for Brazilian manufacturing, including product innovators and non-innovators, exhibits a similar pattern: the propensity to innovate was 19.3% in the class 10-49 employees, 19.1% in the class 50-99 employees, 25.3% in the class 100-249 employees, 28.4% in the class 250-499 employees and 54.3% in the class of 500 or more employees (IBGE, 2005). Equivalent data for South African product innovators and non-innovators (all sectors) show the same pattern: the propensity to innovate was 51% in the

Table 4. Radical product innovation indicators by country, innovators only (%)

No. of employees	Small (10-49)	Medium (50-249)	Large (250 or more)	Total
Propensity				
China	70	67	72	70
Germany	31	40	61	41
Spain	47	52	61	49
France	46	53	62	52
UK	51	41	50	47
Intensity				
China	27	18	19	19
Germany	28	29	46	44
Spain	33	35	35	35
France	13	16	19	18
UK	26	27	28	27
Productivity				
China	306	37	95	100
Germany	85	100	109	100
Spain	59	73	135	100
France	56	58	111	100
UK	169	61	101	100

Source: Jiangsu Province Innovation Survey and the authors' elaboration on the basis of EC (2004).

class 10-49 employees, 72% in the classes 200-249 and 250-499 employees and 75% in the class of 500 and more employees (Oerlemans et al., 2003). Chinese PIP indicators distribution by size is, however, U-shaped and, while propensity is only marginally higher among larger firms, intensity and productivity are far larger among smaller firms.

To sum up, the PIP indicators on size exhibit slightly different trends and further tests may be required, hence extreme caution is necessary in interpreting them. Yet, three factors suggest the possibility of an emerging new feature in corporate innovative behaviour in China: smaller firms account for the highest proportion of innovative sales and workers in smaller firms have a significantly higher innovative performance than in larger firms; this seems to be contrary to international patterns; and smaller firms are particularly strong at product innovation.

Ownership. Turning to ownership, it is worth noting that in Chinese official statistics ownership refers essentially to the type of registration undertaken by a company. This involves both proper control as well as legal and financing classifications. As in the case of size, definitions have changed repeatedly over the years (Jefferson et al., 2003; Wen et al., 2002). China's and Jiangsu Province 2003 statistical yearbooks (JSB, 2003; NBS, 2003) provide a nine major entry classification of ownership. For the purposes of this research, the Chinese classification was used as a starting point and converted into a four-way categorisation.

- State-owned, including state-owned, collective-owned, shareholding co-operatives and joint-operated (state and/or collective) firms from the Chinese official classification.
- Limited liability – companies with fewer than 49 investors, with each investor liable in proportion to their investments and the company liable to a maximum of its total assets. This includes limited responsibility companies as well as some private and minority-owned foreign companies from the Chinese official classification.
- Shareholding – no limit in the number of investors and shares are emitted in proportion to the investment. Liability is restricted to stockholding. Shareholding – same investors rights as limited liability but stocks are issued and there is no cap on the number of shareholders. This includes shareholding firms as well as some private and minority-owned foreign companies from the Chinese official classification.
- Foreign and non-mainland Chinese – companies in which Hong Kong, Macao, Taiwan and foreign nationals account for at least 50% of the total capital. This ownership category also includes Hong Kong, Macao, Taiwan and foreign-funded enterprises from the Chinese classification.[2]

Looking into corporate behaviour by ownership type, the privatisation literature generally claims that state-owned firms are bureaucratic, conservative in their attitude towards risk, inefficient, face soft-budget constraints and are sometimes corrupt – all of which, by implication, is not conducive to innovation (Kikeri and Nellis, 2004; Megginson and Netter, 2001). By contrast, private firms are deemed to be competitive, dynamic, risk-takers, face hard-budget constraints and are generally more effective and efficient and, as a result, more profitable and innovative. Multinational corporations and foreign investors, because of their unique intangible assets, are expected to be extremely innovative in their home countries, although the extent to which they innovate in host countries is subject to greater controversy (Caves, 1996; Dunning, 2001; Kozul-Wright and Rowthorn, 1998; Rasiah, 2007).

The JPIS would seem to confirm some of the expectations in the literature (Table 5). The propensity to innovate radically and incrementally is highest among shareholding firms, although state-owned enterprises (SOEs) also have innovative activities, particularly in terms of incremental innovation. In terms of intensity, however, SOEs are far behind other types of firms, although in process and incremental innovation the gap is narrower – something that seems to be related to the prevalence of old outmoded technology that requires significant production line/process modification and updating. Indeed, Sun (2003: 138) pointed out that many SOEs restructured their productive processes in order to become more competitive, responding to pressures from their sector ministries. At the other end of the innovation intensity spectrum are shareholding and foreign firms. Shareholding firms, particularly in product innovation, seem to be more innovative than limited responsibility companies, suggesting that the need to diversify their product portfolio is linked to financial discipline attached to this type of ownership. In terms of productivity, foreign enterprises are far ahead of other types of ownership, nearly ten times higher in some cases, with workers being most productive at product innovation. Foreign firms tend to be staffed more efficiently and, hence, the large disparities in terms of sales per worker.

Table 5. Radical and incremental innovation by ownership, innovators only (%)

Ownership type	State	Limited liability	Shareholding	Foreign and non-mainland Chinese	Total
Propensity					
Radical					
Product	68.4	69.5	73.7	68.3	70.0
Process	68.1	71.2	80.4	67.6	71.9
Incremental					
Product	94.7	87.8	96.5	90.2	92.0
Process	91.5	87.9	97.8	83.8	90.3
Intensity					
Radical					
Product	12.1	19.6	22.8	24.0	19.3
Process	16.3	21.1	21.7	26.3	21.1
Incremental					
Product	22.7	28.9	32.6	37.9	29.9
Process	27.1	31.9	32.1	33.1	31.0
Productivity					
Radical					
Product	52.4	39.2	82.2	351.3	100
Process	50.3	56.2	86.1	291.0	100
Incremental					
Product	49.4	29.2	67.4	423.3	100
Process	67.7	57.1	111.5	245.7	100

Source: Jiangsu Province Innovation Survey.

Given the controversy surrounding the role of foreign firms in innovation in host countries, we examined other surveys with comparable data. The Argentinean survey, focusing on innovators only, found that the product and process innovation propensity among firms with foreign ownership was 59% and 66%, while the equivalent figures for firms without foreign capital was 42% and 41% (INDEC, 2003). The Australian survey, showing data for innovators and non-innovators in all industries, found a propensity to innovate of 33.7% among purely Australian and of 59.2% for companies with more than 50% foreign ownership (ABS, 2006). Two points should be considered with regard to this. First, limited as this evidence is, it does lend some further credibility to the Chinese findings. Secondly, the possibility of foreign firms being a significant direct contributor to local innovative capacities in host countries, is one not very much considered in the literature and certainly worth exploring.

Industry. Industries generally refer to aggregations of units of production selling similar goods. They differ in a number of characteristics – concentration levels, extent of barriers to entry, degree of product differentiation and advertising, levels of investment in machinery and equipment and R&D, nature of the production process, relationship between inputs and output and the amount of knowledge requirements –to mention just a few. This research used the Chinese and Jiangsu Province manufacturing industry statistics based on a 29 two-digit entry classification. To make the data tractable and internationally comparable, the study aggregated the Chinese classification into 11 sectors equivalent to the EU's classification of economic activities.

The propensity to innovate radically was higher among machinery and equipment, wood and food producers (Table 6). In terms of incremental innovation, the wood, plastic and metal industries had propensities suggesting all firms in these industries had some innovative activity, something that was also the case for incremental process innovation in the machinery and equipment industry. Radical innovation intensity was higher in the food and machinery and equipment industries, although radical process innovation was highest in the vehicle industry. Incremental innovation intensity was higher in the chemicals, metal and electrical machinery, but incremental process innovation is also rather high in the plastics and machinery and equipment industries. Radical innovation productivity is by far the highest in the textile industry, while incremental innovation productivity is highest in the electrical machinery industry. Jiangsu Province's textile industry has witnessed over recent years the entry of foreign modern capital-intensive fabric firms aimed both at exporting and catering for an increasingly diverse local market.

The growing domestic demand for new and more functional household appliances, such as fridges and washing machines, partially explains the extent of product radical and incremental innovation in the electrical and non-electrical machinery and equipment industries. Jiangsu Province is also rapidly becoming a leading producer and exporter of computer-controlled machine tools and hand-held power tools (JSB, 2003; NBS, 2003). Innovation in the food industry seems related to the growing mass production of traditional Chinese food products and the imitation and/or adaptation of foreign sweets, biscuits and related products. Process radical and incremental innovation in the electrical equipment industry is related to

Table 6. Radical and incremental innovation by industry, innovators only (%)

	Propensity				Intensity				Productivity			
	Radical		Incremental		Radical		Incremental		Radical		Incremental	
Industry	Product	Process	Product	Process	Product	Process	Product	Process	Product	Process	Product	Process
Food	85.7	72.7	81.0	86.4	32.4	26.4	19.8	26.6	133.1	149.6	34.2	65.5
Textile	78.9	68.8	94.7	93.8	18.2	21.3	24.8	25.7	379.3	439.4	124.2	100.0
Wood	87.5	83.3	100.0	100.0	20.1	24.2	26.4	25.0	20.5	30.4	13.5	27.2
Chemicals	56.4	62.5	92.3	81.3	16.7	21.4	33.3	30.6	38.5	71.0	66.3	104.3
Plastic	78.6	75.0	100.0	100.0	20.2	16.9	29.4	42.7	22.3	19.4	37.6	83.0
Non-metal	25.0	50.0	75.0	50.0	2.5	5.0	31.3	10.0	4.7	11.3	33.6	2.0
Metal	43.5	55.0	100.0	100.0	8.5	9.1	38.0	36.9	3.7	5.5	28.9	58.0
Machinery and equipment	87.5	92.0	93.8	100.0	26.2	26.9	28.2	36.6	52.8	62.3	43.6	102.6
Vehicles	64.7	80.0	88.2	80.0	17.5	35.5	29.3	18.1	101.9	233.7	34.6	46.5
Electrical machinery	70.0	73.5	90.0	91.2	15.2	14.8	34.9	36.9	179.7	51.0	374.6	220.0
Other	78.3	73.7	87.0	84.2	27.6	27.2	23.3	21.7	81.6	74.7	29.0	49.0
Total	70.4	72.2	91.7	90.4	19.6	21.2	29.7	31.1	100	100	100	100

Source: Jiangsu Province Innovation Survey.

companies striving for higher efficiency due to competition from a growing number of Chinese and foreign household goods-producing companies. In the plastic industry, processes seem to be changing due to the need to achieve higher-scale economies in the production of tyres and construction plastics (JSB, 2003; NBS, 2003).

In order to assess the relative importance of innovation in different industries it must be stressed that Chinese industry's propensity to innovate seems to be similarly ranked to that in other countries. The propensity to innovate products in Canadian industry was over 90% in all sub-sectors of the electrical machinery, chemical, plastics and machinery industries (Statistics Canada, 2002). Leading product innovative industries in Brazil were textiles, chemicals, machinery and equipment and electrical equipment while, in South Africa, electrical equipment and transport equipment seem to be the most innovative (IBGE, 2005; Oerlemans et al., 2003). Leading process innovative industries in Brazil were food, textiles, wood and vehicles while, in South Africa, electrical equipment and transport equipment also seem to have the highest propensities (IBGE, 2005; Oerlemans et al., 2003). These similarities in rankings suggest industry, rather than national factors alone, explain the propensity to innovate.

The Market m = Magnitude of Innovation : Degree of Novelty

Thus far the focus has been the technical dimension of innovation. In this section we will turn our attention to the degree of novelty of innovation. To examine who innovates what, the PIP indicators will be discussed in the context of our four firm characteristics: innovations new to the world, new to China, new to the Jiangsu Province market and new to the firm. As in the previous section, the focus will be on innovators only.

Size. In terms of innovations new to the world, the product and process propensity was highest among large firms in the 501-1000 and 2001-5000 employees brackets but, once intensity and productivity indicators are taken into account, it is smaller firms, in the 10-49 workers group, that come out on top, both in new products and processes (Table 7). Indeed, workers in this size group produce at least seven times more innovation than the average for all size groups. Innovations new to China exhibit a less clear-cut pattern. While the product and process propensity are highest among larger firms (2001-5000 and 5000 or more workers), the product intensity is highest among the 250-500 employees class and the process intensity is highest among the 2001-5000 workers group. Product and process productivity is, however, highest among the 250-500 employees class. As far as innovations new to Jiangsu Province are concerned, all three product and process PIP indicators were highest among small firms. In terms of "catching up" innovation, the product and process propensity is higher among large firms (5001 or more and 501-1000 workers groups), the product and process intensity is higher among medium-sized firms (50-249 employees) and the product and process productivity is highest among small firms. Altogether, it seems that smaller firms engage in much more novel product and process innovative activities and are very efficient at innovating, medium firms engage in less novel activities, while large firms get involved in relatively more novel process activities – at least when compared with medium enterprises.

Table 7. Degree of novelty of innovations by firm size, innovators only (%)

No. of employees	10-49	50-249	250-500	501-1000	1001-2000	2001-5000	5001 or more	Total
Propensity								
World								
Product	33.3	16.3	28.6	34.8	23.5	35.7	12.5	25.8
Process	40.0	26.7	31.0	53.8	33.3	60.0	40.0	36.7
China								
Product	75.0	69.8	66.7	65.2	70.6	92.9	87.5	71.7
Process	60.0	56.7	72.4	61.5	75.0	90.0	100.0	68.8
Jiangsu								
Product	83.3	60.5	47.6	78.3	70.6	78.6	50.0	63.5
Process	90.0	56.7	51.7	84.6	66.7	80.0	60.0	65.1
Firm								
Product	75.0	74.4	78.6	73.9	70.6	71.4	87.5	75.5
Process	80.0	86.7	75.9	92.3	75.0	80.0	80.0	81.7
Intensity								
World								
Product	14.5	3.2	3.5	7.2	1.7	9.0	0.9	4.9
Process	19.0	7.8	4.0	13.8	1.4	13.8	1.6	8.1
China								
Product	11.3	14.6	15.7	7.7	13.7	14.6	6.9	13.2
Process	13.2	7.3	18.4	4.7	8.5	20.5	11.9	12.1
Jiangsu								
Product	12.6	8.5	7.6	9.0	9.9	11.9	5.6	8.9
Process	17.1	11.0	6.3	11.8	8.0	12.1	11.4	10.2
Firm								
Product	21.8	22.4	21.9	20.5	17.3	19.6	17.6	20.9
Process	13.9	31.1	16.1	19.6	15.3	21.6	23.0	21.2
Productivity								
World								
Product	720.7	6.0	125.3	17.2	15.6	66.8	1.3	100
Process	787.7	23.4	23.9	21.3	13.9	84.9	5.5	100
China								
Product	98.7	60.4	197.8	68.2	55.7	80.1	24.7	100
Process	149.0	45.7	165.4	61.9	59.8	139.8	62.7	100
Jiangsu								
Product	248.1	73.7	92.1	113.9	72.0	114.9	39.7	100
Process	232.6	59.3	53.5	183.3	55.5	153.7	104.9	100
Firm								
Product	175.7	114.1	73.8	91.5	89.2	95.3	113.3	100
Process	181.0	76.7	59.9	130.9	90.4	148.3	132.4	100

Source: Jiangsu Province Innovation Survey.

Ownership. As can be seen in Table 8, product and process innovations new to the world were by far, for all three PIP indicators, highest in the case of non-mainland Chinese and foreign companies. In terms of innovations for China, the product propensity indicator is highest for state-owned firms, while the process propensity is highest for shareholding firms. However, intensity and productivity indicators are highest for foreign firms. In the case of Jiangsu Province innovation, product

Table 8. Degree of novelty of innovations by ownership, innovators only (%)

Ownership type	State	Limited liability	Shareholding	Non-mainland Chinese and foreign	Total
Propensity					
World					
Product	20.9	19.0	28.9	51.6	27.7
Process	27.3	35.0	37.0	62.5	38.7
China					
Product	83.7	69.0	71.1	67.7	72.9
Process	72.7	70.0	85.2	58.3	71.8
Jiangsu					
Product	79.1	55.2	77.8	45.2	65.0
Process	78.8	57.5	81.5	50.0	66.9
Firm					
Product	76.7	74.1	86.7	51.6	74.0
Process	87.9	85.0	92.6	58.3	82.3
Intensity					
World					
Product	1.7	2.2	2.1	19.7	5.1
Process	1.6	6.6	4.3	22.4	7.8
China					
Product	9.5	16.1	11.1	25.3	14.8
Process	7.8	14.0	10.8	16.6	12.2
Jiangsu					
Product	9.8	8.1	13.9	5.0	9.5
Process	12.5	8.4	10.6	5.6	9.4
Firm					
Product	17.0	22.3	26.5	11.7	20.2
Process	21.6	25.2	21.0	10.8	20.6
Productivity					
World					
Product	4.1	3.7	43.6	613.4	100
Process	4.5	15.0	41.1	585.8	100
China					
Product	43.4	66.7	144.8	186.7	100
Process	46.0	87.6	169.3	115.8	100
Jiangsu					
Product	146.3	53.0	167.7	47.4	100
Process	144.7	83.1	111.7	53.0	100
Firm					
Product	134.5	79.5	119.2	64.6	100
Process	109.3	89.5	122.1	81.3	100

Source: Jiangsu Province Innovation Survey.

propensity is highest among state-owned firms but process propensity is highest among shareholding firms. Product intensity and productivity are highest in shareholding firms, while process intensity and productivity was highest among state-owned companies. As far as innovations new to the firm are concerned, shareholding firms have the highest product and process propensity, the highest product intensity and highest process productivity, while limited liability companies have the highest product innovation intensity and state-owned firms the highest process productivity. Clearly, non-mainland Chinese and foreign firms achieve the highest degree of novelty and the data suggest that these firms use China as their launching pad for some of their new products aimed at world markets. They are also competing locally and internationally by improving process efficiency and reducing costs, thus the high productivity indexes. The extent of novelty is somewhat in the middle for shareholding firms and, surprisingly, for state-owned firms, which are doing relatively well in process innovation.

Industry. The propensity to innovate products new to the world was higher in the textile, wood and metal industries, while the propensity to innovate processes new to the world is higher in the textile, wood, metal and machinery industries (Table 9). Intensity and productivity indicators are, nevertheless, by far the highest in the textile industry. Turning to innovation new to China, the propensity to innovate was higher in the metal, machinery, electric machinery and vehicle industries, while the process propensity was higher in the plastic, metal, machinery and vehicle industries. The intensity was higher in the chemical, plastic, machinery and vehicle industries, but the productivity was highest in the textile and vehicle industries. In terms of innovations new to Jiangsu Province, the product and process propensity was higher in the food, textile (except process), chemical and machinery (except product) industries; the product and process intensity was higher in the food and chemical industries; and the productivity was higher in the food, textile and chemical industries. As far as catching up innovations are concerned, product and process propensity indicators are higher in the food, wood, plastic and electric machinery (except product) industries. Product intensity was higher in food, wood and plastics, while process intensity was higher in wood, plastics and electrical machinery.

Product productivity was higher in food textiles and chemicals, while process productivity was higher in the food, non-electrical and electrical machinery industries. Altogether, it is in textiles where the most novel products and processes seem to be emerging and, indeed, innovation in the textile industry seems to cut across all degrees of novelty. Industries where the degree of novelty is somewhat in the middle include the food, wood, chemicals and machinery industries.

Why Do Firms Innovate?

In order to probe into why firms innovate, the JPIS identified a number of possible reasons for undertaking innovation, on the basis of reviewing some key empirical contributions in the innovation literature (Baldwin, 1996; Baldwin and Lin, 2002; Gellatly, 1999; Rosa, 2002). Thirteen key motives were identified, as shown on Figure 1. They include some "generic" marketing, technological and economic objectives underlying innovation, such as improving general competitiveness and product quality, creating or expanding market share and extending product range. They comprise "R&D projects undertaken by competitors" and "competitors R&D expenditure," which are in line with what Freeman and Soete (1997: 272-3) dubbed "defensive" innovation strategies, where firms undertake R&D. However, unlike "offensive" counterparts, they do not seek to actively generate competitive advantages from technology but only protect themselves from competition. They

Table 9. Degree of novelty of innovations by industry, innovators only (%)

	Propensity				Intensity				Productivity			
Industry	World	China	Jiangsu	Firm	World	China	Jiangsu	Firm	World	China	Jiangsu	Firm
Food												
Product	10.5	52.6	78.9	89.5	1.3	12.0	13.4	25.7	3.7	21.3	230.3	199.3
Process	16.7	41.7	91.7	83.3	3.6	1.6	18.1	17.0	9.3	34.0	158.7	184.5
Textile												
Product	50.0	75.0	81.3	62.5	16.9	6.7	8.5	13.3	830.1	293.7	230.3	201.2
Process	75.0	66.7	58.3	75.0	26.5	8.3	6.3	11.4	1052.1	258.7	63.6	73.8
Wood												
Product	50.0	33.3	50.0	100.0	5.2	1.5	3.7	48.0	13.8	2.6	7.8	77.2
Process	75.0	50.0	75.0	100.0	4.3	2.0	17.1	24.1	9.2	4.5	86.3	67.8
Chemicals												
Product	20.7	75.9	72.4	69.0	2.1	18.6	13.9	15.9	8.2	67.3	97.0	82.7
Process	33.3	71.4	71.4	76.2	6.6	10.4	12.6	14.7	26.3	103.2	128.8	69.7
Plastic												
Product	25.0	62.5	50.0	87.5	3.9	15.1	6.1	25.6	4.0	124.8	16.1	29.2
Process	25.0	75.0	37.5	87.5	7.3	15.2	4.1	31.9	6.2	158.1	10.8	47.8
Non-metal												
Product	0.0	0.0	50.0	75.0	0.0	0.0	3.0	30.8	0.0	0.0	18.6	91.6
Process	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Metal												
Product	52.9	76.5	64.7	76.5	7.4	14.6	7.7	18.4	10.9	13.5	17.2	61.0
Process	53.8	76.9	69.2	69.2	4.5	15.5	8.9	24.0	5.1	27.0	21.0	58.3
Machinery and equipment												
Product	40.9	81.8	63.6	81.8	4.1	22.7	8.4	19.0	14.5	106.6	90.2	63.5
Process	52.9	88.2	76.5	82.4	6.3	23.8	12.7	23.8	8.2	117.7	107.8	115.9
Vehicles												
Product	22.2	100.0	33.3	44.4	2.2	26.2	5.4	8.5	4.0	180.2	30.3	30.6
Process	33.3	100.0	50.0	83.3	8.7	18.5	4.7	13.0	6.8	173.6	67.7	65.0

(continued)

Table 9. (*Continued*)

	Propensity				Intensity				Productivity			
Industry	World	China	Jiangsu	Firm	World	China	Jiangsu	Firm	World	China	Jiangsu	Firm
Electric machinery												
Product	22.9	77.1	62.9	68.6	7.2	12.3	10.1	19.8	156.4	145.4	80.0	85.2
Process	26.1	65.2	60.9	91.3	7.5	8.2	8.7	24.4	42.4	75.3	108.5	125.5
Other												
Product	6.7	86.7	60.0	73.3	0.5	21.4	7.2	23.4	0.0	52.8	100.8	128.9
Process	11.1	77.8	66.7	77.8	0.4	15.0	5.9	21.4	0.0	51.7	158.0	137.6
Total												
Product	27.8	72.8	65.0	73.9	5.1	15.2	9.5	20.1	100	100	100	100
Process	38.4	71.2	67.2	81.6	7.8	12.1	10.2	20.4	100	100	100	100

Source: Jiangsu Province Innovation Survey.

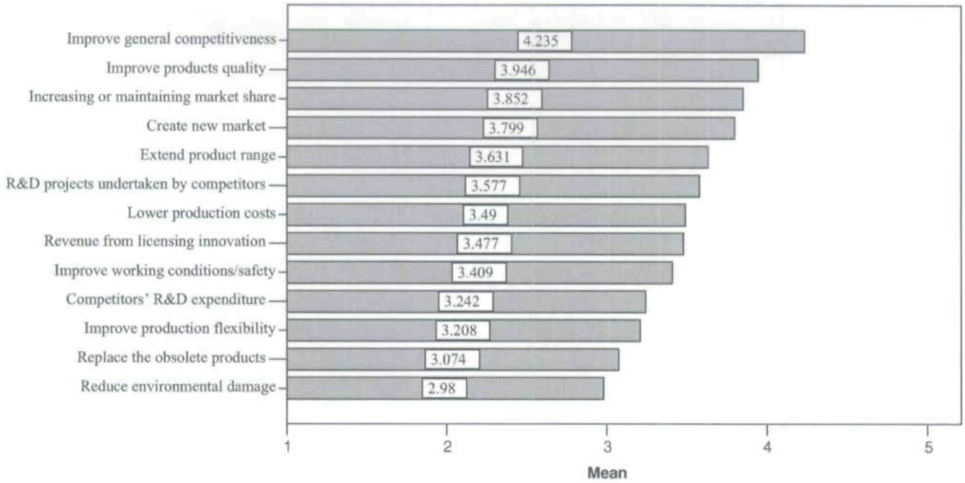

Figure 1. Innovation objectives. *Source*: Jiangsu Province Innovation Survey

contain "offensive" criteria, such as "obtaining license fees from technological development," as well as objectives such as improving production flexibility, lowering of production costs and replacing obsolete products. These would, perhaps, fall under Freeman and Soete's (1997: 268-71) "traditional and imitative" innovation strategies, where firms compete on the basis of improving their operational conditions and efficiency. Finally, there are "altruistic" objectives, such as improving working conditions and safety and reducing environmental damage. A Likert five-point scale was included in the survey, ranging from not at all important to critically important, which was then averaged for presentation purposes. Both innovative and non-innovative firms provided answers.

By and large, the most important objective underlying innovation is to improve general competitiveness. Managers in China seem to be clearly aware of the relationship between developing new products and processes and their relative position *vis à vis* their domestic and international competitors. Indeed, the next four top objectives – improving product quality, increasing or maintaining market share, extending product range and creating new markets – can be seen as specific manifestations of this more "generic" competitiveness objective. The next objectives by importance were responding to R&D projects undertaken by competitors, lowering production costs and obtaining revenue from licensing. Bottom of the list was reducing environmental damage.

Digging deeper into the drivers of innovation also required testing whether there were differences in objectives between innovative and non-innovative firms. To the extent that innovators face unique efforts and risks and thus may seek to achieve specific objectives, it is to be expected that innovative and non-innovative firms would have a dissimilar attitude *vis à vis* individual objectives and their groupings. To check for this, a number of non-parametric Mann-Whitney U statistical tests were conducted on each of the innovation objectives obtained in the survey. In this case all firms that answered yes/no to innovation questions were included. Table 10

Table 10. Innovation objectives for all and radical innovations

		All innovations					Radical innovations				
	Type of firm	*n*	Mean	Mean rank	Mann-Whitney U	Asymp. Sig. (2-tailed)	*n*	Mean	Mean rank	Mann-Whitney U	Asymp. Sig. (2-tailed)
Improve general competitiveness	Non-innovative	21	3.7	121.5	2321.0	0.054	79	4.0	112.0	5684.5	0.058
	Innovative	288	4.2	157.4			167	4.3	129.0		
Improve products quality	Non-innovative	22	3.3	105.5	2069.0	0.004	80	3.6	99.1	4690.0	0.000
	Innovative	288	4.1	159.3			166	4.2	135.2		
Increasing/maintaining market share	Non-innovative	20	3.5	126.0	2309.0	0.190	76	3.8	116.8	5951.0	0.555
	Innovative	277	3.9	150.7			164	3.9	122.2		
Create new market	Non-innovative	15	3.2	95.9	1318.0	0.094	60	3.6	92.0	3688.5	0.198
	Innovative	232	3.8	125.8			138	3.9	102.8		
Extend product range	Non-innovative	21	3.2	108.6	2050.5	0.010	80	3.4	104.8	5147.0	0.006
	Innovative	285	3.8	156.8			162	3.8	129.7		
R&D projects undertaken by competitors	Non-innovative	19	2.9	98.0	1672.0	0.013	73	3.2	89.6	3842.0	0.000
	Innovative	261	3.6	143.6			155	3.7	126.2		
Lower production costs	Non-innovative	11	3.3	89.8	922.0	0.566	43	3.2	70.6	2089.5	0.102
	Innovative	186	3.5	99.5			116	3.6	83.5		
Revenue from licensing innovation	Non-innovative	21	3.0	108.8	2053.5	0.041	77	3.2	97.0	4465.5	0.000
	Innovative	263	3.6	145.2			160	3.7	129.6		
Improve working conditions/safety	Non-innovative	20	2.9	107.0	1930.0	0.022	74	3.1	99.4	4581.5	0.004
	Innovative	273	3.5	149.9			160	3.5	125.9		
Competitors' R&D expenditure	Non-innovative	17	2.8	99.8	1544.0	0.043	70	2.9	87.1	3611.5	0.000
	Innovative	253	3.4	137.9			151	3.5	122.1		
Improve production flexibility	Non-innovative	18	3.1	124.5	2070.0	0.446	70	2.9	94.7	4143.5	0.005
	Innovative	256	3.2	138.4			152	3.3	119.2		
Replace the obsolete products	Non-innovative	19	2.9	121.7	2122.5	0.224	72	3.3	115.0	5582.0	0.939
	Innovative	266	3.3	144.5			156	3.3	114.3		
Reduce environmental damage	Non-innovative	21	2.5	112.1	2122.5	0.036	78	2.8	105.1	5113.0	0.020
	Innovative	276	3.1	151.8			160	3.2	126.5		

Source: Jiangsu Province Innovation Survey.

shows the SPSS output for the thirteen objectives for all innovations and for radical innovations.

Taking all innovations first, and considering significant differences between innovators and non-innovators at the 0.05 and 0.01 levels, the data show that in seven out of the thirteen objectives both types of firms differ. Innovative firms attach much higher values to differing objectives than non-innovative firms. Interestingly enough, "defensive strategy" objectives, such as R&D projects undertaken by competitors and competitors' R&D expenditure, are significantly different between innovators and non-innovators. Equally, there are significant differences between innovative and non-innovative firms in the "offensive" strategy objective of companies seeking to use their technological ability as a means of generating licence fees. Innovative and non-innovative firms also differ in their seeking to improve worker safety and reducing environmental damage. This is consistent with Maidique and Hayes (1984: 25) contention that high-tech innovative firms tend to have a "stakeholder" rather than a shareholder approach; that is, they try to accommodate for all interested parties in the firm and are more responsive to demands from society. Finally, innovative and non-innovative firms differ in two more "general type" corporate objectives, extending product range and improving product quality. To the extent that these are objectives that all firms pursue, e.g. improving general competitiveness, in principle there should be no differences between both types of firms. However, the fact that firms differ may be explained by those firms engaging in innovation actually observing improvements in their product range and quality. Thus, the objective may be reflecting prior positive experiences with innovation, which was not the case with other "generic" objectives.

Moving on to differences between innovative and non-innovative firms' radical innovation, the findings are also quite informative. The data were constructed on the basis of sales share, so all firms declaring sales of radical innovations were included, independent of their share. The focus on radical and not on incremental innovation stems from the fact that many firms in China have already developed the capacity of achieving higher-level innovative activity and that examining what accounts for such behaviour is of paramount academic, practical and policy interest. Also, most of the international comparative data refer to radical innovation. Confirmatory tests (not reported here) performed on incremental innovation at earlier stages of this study showed few differences emerging between innovative and non-innovative firms.

For radical innovation there were eight objectives in which innovators and non-innovators differed. These included the same seven objectives for all innovations and improving production flexibility. In the seven objectives essentially there was an improvement in the significance levels, suggesting much more acute differences between both groups than in the case of all innovations. Innovative firms also pursue these objectives far more intensively than non-innovative firms. The production flexibility improvement objective may differ also due to the experience factor as this tends to be a "traditional strategy" objective. It is worth noting that differences between innovative and non-innovative firms regarding the objectives of workers safety and reduction of environmental damage are quite consistent with Baldwin and Johnson's (1995) study. This study was based on a 1992 survey of growing small and medium-sized Canadian firms and found that innovative firms care much more for their workforce than non-innovative firms. Also, Gellatly (1999), focusing on business services firms under 50 employees from Canada's 1996 Innovation Survey, found innovative firms giving far better treatment and more training to their wokers than non-innovative firms.

What Limits Innovation?

Innovation can be hampered seriously by a number of economic, financial, organisational, marketing, technological and government-related impediments and problems. It is accepted widely that firms obtain major benefits from innovation but, in order to do so, they need to surmount a great number of difficulties (see Baldwin and Lin, 2002). Economic barriers arise from cost, risk and appropriability considerations and from the fact that innovation generally requires higher skills (Baldwin, 1996; Baldwin and Lin, 2002; Gellatly, 1999; Mohnen and Rosa, 1999; Tourigny and Le, 2004; Vermeulen, 2005). Financial impediments are linked mainly to access to capital (Baldwin and Lin, 2002; Mohnen and Rosa, 1999; Tourigny and Le, 2004; Vermeulen, 2005). Organisational problems arise from the inertia emerging within organisations as activities get routinised and the difficulties related to changing such inertia (Gellatly, 1999; Mohnen and Rosa, 1999; Vermeulen, 2005; Zell, 2001). Marketing difficulties arise out of internal and external information asymmetries and market uncertainties (Baldwin, 1996; Baldwin and Johnson, 1996; Baldwin and Lin, 2002; Dougherty, 1992; Mohnen and Rosa, 1999; Tourigny and Le, 2004). Technological problems arise out of information asymmetries, imperfections in the markets for knowledge and technical complexities involved in radical innovation (Baldwin, 1996; Baldwin and Lin, 2002; Tourigny and Le, 2004; Vermeulen, 2005; Zell, 2001). Government-related obstacles emerge from the extent of availability of supportive institutions, the nature of existing regulations and policies and the inter-institutional linkage efforts made by the government (Baldwin, 1996; Baldwin and Lin, 2002; Frenkel, 2003; Tourigny and Le, 2004).

To examine which types of impediments and problems were faced by innovative firms in China, the JPIS provided a list of nineteen possible obstacles for firms to select based on the available literature. Figure 2 gives the list of obstacles as well as their average scoring (see also An et al., 2005). As before, firms were given a choice from a five-point Likert scale, ranging from insignificant to crucial. Firms in China perceived technical obstacles as the most difficult to surmount. Enterprises' inadequate technical potential, lack of technical information and technological opportunities and limited knowledge co-operation with outside firms averaged 3.07. Lack of access to finance was the second highest impediment to innovation, averaging 2.95, followed by marketing (2.89) and economic (2.87) obstacles. Economic obstacles included excessive risk, high or uncontrollable costs, ease of copy, lack of skilled staff, long pay-off period and ownership types. Marketing limitations involved poor market responsiveness and market information and uncertainties related to launching timing. Government-related impediments, including regulations and technical assistance, and organisational limitations, such as resistance to change and "locking" to old technologies, were the least important ones.

Analysing differences in obstacles to innovation faced by innovative and non-innovative firms required conducting further Mann-Whitney U statistical tests. As can be appreciated in Table 11, there was hardly any significant difference between

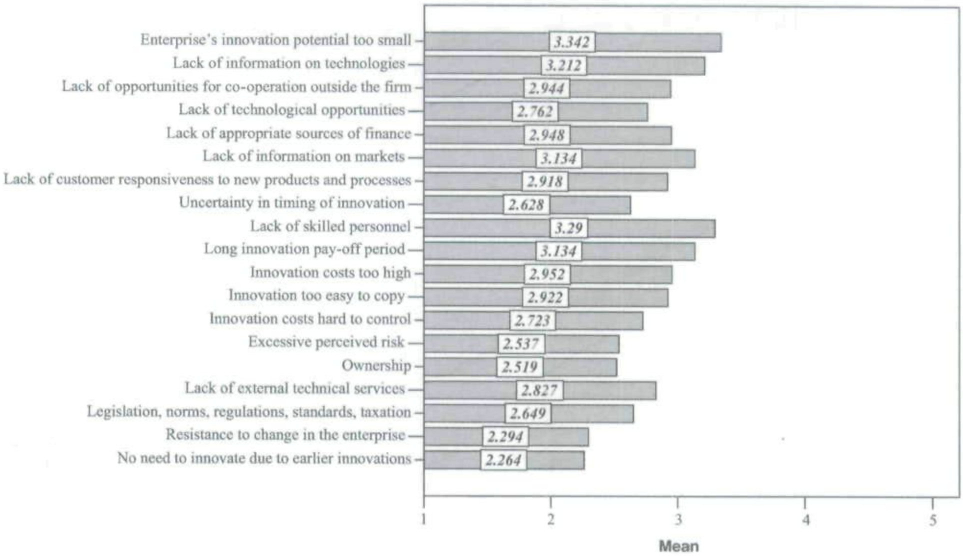

Figure 2. Innovation obstacles. *Source*: Jiangsu Province Innovation Survey

the two types of firm except for the obstacle of lack of technological opportunities, which was significant at the 0.05 level. This was rather surprising, as one would expect some more differences emerging out of what Baldwin and Johnson (1996), Baldwin and Lin (2002) and Gellatly (1999) termed *ex-ante* and *ex-post* impediments. *Ex-ante* obstacles arise prior to making innovation investments, while *ex-post* obstacles arise out of firms actually undertaking innovation programmes. As with objectives, firms actually undertaking innovation may have already faced some obstacles that they perceive with much more trepidation than non-innovative firms. However, lack of differences may result from the inclusion of process and incremental innovation, which normally involve far less difficulties than radical innovation.

Indeed, differences between innovative and non-innovative firms carrying out radical innovation were much more apparent (Table 11). As with objectives, all firms that declared sales of radical innovations were included, independent of their share. All technical obstacles were significant at the 0.05 and 0.01 levels. According to Baldwin and Lin (2002), radical innovators tend to be highly technically orientated firms and, due to their practical experiences with these difficulties, have a far better understanding than non-innovators of the technical and knowledge requirements and interactions, as well as of the potential problems to be faced in the innovation process. Another obstacle differentiating firms was lack of access to finance. This is a well-known impediment faced mainly, though not exclusively, by SMEs (Hadjimanolis, 1999; Vermeulen 2005). Although improving, established Chinese banks and financial institutions still tend to shun innovative projects due to the high risks involved and their lack of experience in assesing such projects, while internally financed projects are competing with projects that involve far less uncertainties. There are also very few venture capitalists in China, despite recently established

Table 11. Obstacles to innovation for all and radical innovations

		All innovations					Radical innovations				
	Type of firm	*n*	Mean	Mean rank	Mann-Whitney U	Asymp. Sig. (2-tailed)	*n*	Mean	Mean rank	Mann-Whitney U	Asymp. Sig. (2-tailed)
Enterprise's innovation potential too small	Non-innovative	22	3.0	108.8	2141.5	0.058	72	3.1	98.2	4441.0	0.015
	Innovative	254	3.4	141.1			153	3.5	120.0		
Lack of information on technologies	Non-innovative	20	3.1	137.8	2545.5	0.658	71	2.9	99.2	4490.0	0.007
	Innovative	270	3.2	146.1			161	3.3	124.1		
Lack of opportunities for co-operation outside the firm	Non-innovative	22	2.7	125.1	2498.5	0.269	70	2.6	97.7	4356.5	0.005
	Innovative	263	3.0	144.5			160	3.0	123.3		
Lack of technological opportunities	Non-innovative	21	2.3	100.1	1871.0	0.018	68	2.4	90.0	3772.0	0.000
	Innovative	254	2.8	141.1			155	2.9	121.7		
Lack of appropriate sources of finance	Non-innovative	21	2.8	124.6	2386.5	0.296	71	2.6	98.9	4469.0	0.011
	Innovative	262	3.0	143.4			158	3.0	122.2		
Lack of information on markets	Non-innovative	23	3.1	143.6	3027.0	0.883	74	2.8	101.0	4702.5	0.011
	Innovative	268	3.1	146.2			159	3.3	124.4		
Lack of customer responsiveness to new products and processes	Non-innovative	21	2.7	112.2	2125.0	0.133	69	2.7	98.1	4354.0	0.022
	Innovative	250	3.0	138.0			155	3.1	118.9		
Uncertainty in timing of innovation	Non-innovative	22	2.6	130.1	2609.0	0.615	67	2.5	101.2	4504.0	0.091
	Innovative	253	2.7	138.7			156	2.8	116.6		
Lack of skilled personnel	Non-innovative	24	3.1	130.9	2840.5	0.224	77	3.1	109.5	5432.0	0.079
	Innovative	276	3.3	152.2			163	3.4	125.7		
Long innovation pay-off period	Non-innovative	22	3.3	149.0	2894.0	0.859	73	3.0	104.3	4912.0	0.044
	Innovative	269	3.2	145.8			160	3.3	122.8		
Innovation costs too high	Non-innovative	20	3.1	149.0	2751.0	0.980	72	2.8	111.6	5409.5	0.258
	Innovative	276	3.0	148.5			165	3.0	122.2		
Innovation too easy to copy	Non-innovative	21	2.8	121.6	2323.0	0.265	66	2.8	100.5	4420.5	0.066
	Innovative	258	3.0	141.5			158	3.1	117.5		

(continued)

Table 11. (*Continued*)

		All innovations					Radical innovations				
	Type of firm	*n*	Mean	Mean rank	Mann-Whitney U	Asymp. Sig. (2-tailed)	*n*	Mean	Mean rank	Mann-Whitney U	Asymp. Sig. (2-tailed)
Innovation costs hard to control	Non-innovative	21	2.7	137.5	2656.5	0.720	69	2.4	97.6	4318.5	0.008
	Innovative	265	2.8	144.0			159	2.8	121.8		
Excessive perceived risk	Non-innovative	21	2.6	137.6	2659.5	0.793	71	2.6	107.4	5072.0	0.331
	Innovative	262	2.7	142.3			155	2.7	116.3		
Ownership	Non-innovative	21	2.2	108.2	2041.0	0.228	67	2.4	98.3	4306.5	0.151
	Innovative	230	2.6	127.6			146	2.7	111.0		
Lack of external technical services	Non-innovative	22	2.6	118.7	2357.5	0.125	70	2.6	95.4	4190.5	0.002
	Innovative	264	2.9	145.6			158	3.1	123.0		
Legislation, norms, regulations, standards, taxation	Non-innovative	22	2.6	132.0	2650.0	0.747	68	2.5	102.4	4617.0	0.113
	Innovative	251	2.7	137.4			156	2.8	116.9		
Resistance to change in the enterprise	Non-innovative	21	2.2	133.3	2569.0	0.642	68	2.1	101.5	4554.0	0.081
	Innovative	260	2.4	141.6			156	2.4	117.3		
No need to innovate due to earlier innovations	Non-innovative	22	2.1	122.7	2445.5	0.357	67	2.1	101.5	4519.5	0.148
	Innovative	251	2.4	138.3			153	2.3	114.5		

Source: Jiangsu Province Innovation Survey.

government funds. Marketing obstacles differentiating firms included poor perception of products by markets and lack of market information, suggesting that innovators have probably already tried and failed in coming up with completely new products and processes. Economic obstacles perceived as higher by innovative firms included limitations to control innovation costs and the long repayment period of innovative investments. This also suggests that innovative firms may have actually experienced the long and protracted process involved in developing significantly new products and processes, which is normally characterised by project delays, cost overruns and significant lags in recovering investments (Wheelwright and Clark, 1992). Finally, lack of technical support by government agencies was also perceived as a major obstacle by radical innovators, presumably because they are demanding such services.

The findings for radical innovation in China seem to be in line with what other studies comparing obstacles faced by innovators report. Baldwin and Lin (2002), comparing plant adopters and non-adopters of advanced technology from Canada's 1993 Innovation and Advanced Technology Survey, found that cost and skill factors were the most important difficulties faced by adopters. Resistance to change both by management and workers was another important obstacle, followed by government-related difficulties and marketing and technical information deficiencies. Gellatly (1999), focusing on business services firms under 50 employees from Canada's 1996 Innovation Survey, found that innovators encounter more obstacles in ease of copying, market access and finding skilled labour. Galia and Legros (2004), using French data from the EU's 1994-96 Innovation Survey (CIS2), found that firms postponing innovation projects face economic risk, mounting innovation costs, organisational rigidities and lack of skilled personnel, customer responsiveness and technological information as key obstacles. Firms abandoning innovation projects tend to face economic risks more than technological or organisational ones.

Conclusions

China has been trying to develop a technological and innovative capacity in manufacturing for more than 60 years. It has experimented with a wide range of approaches that included top-down dirigiste methods, self-reliant workers' dominated schemes and, nowadays, increasingly market-led practices. The post-1978 reform policies have gone some way in building an innovation system that is decentralised and efficient. There has been a shift of technological activities away from government and into firms, R&D expenditure has doubled, the number of local and international patents has increased and, up to the end of the last decade, innovation was on the rise.

The emerging changes had a large impact over innovative and technological efforts across China and, especially, in Jiangsu Province, where this study was conducted. Indeed, in addressing the first research question on the extent of innovation, the data demonstrated that a relatively large proportion of firms in China engage in innovation, although the amount of sales arising from those activities is on the lower end of the international scale. Most of the innovation is incremental and, in terms of degree of novelty, firms in China displayed a small proportion of world innovations, although there are few reference points to compare with. The largest share of innovation is for "catching-up" purposes, but there are significant efforts to develop new products and processes new to the country and province. There are areas where China is beginning to innovate for the world but this is far from making China a major player in world innovation. Indeed, China's role in the international division of labour still remains that of a source of cheap manufactured goods.

The analysis of propensity-intensity-productivity (PIP) indicators was aimed at examining what was innovated and by whom. The data for the technical dimension of innovation, radical or incremental, showed that small firms, foreign firms and enterprises in the food, chemicals, textile and machinery and equipment industries had the highest share of innovation sales and productivity per worker. It also showed for the degree of novelty dimension of innovation that small firms, foreign firms and enterprises in the textile industry had the most advanced levels on the basis of intensity and productivity indicators. Small and foreign firms and the textile industry seem to be emerging as the drivers of innovative activity.

Turning to the question of why firms innovate, the study found a number of "generic" objectives related to improving competitiveness, "defensive" objectives linked to responding to competitors' innovation efforts, and "offensive" objectives related to obtaining income from technology, as the principal motivators for innovation. Also, innovators valued significantly higher these objectives than non-innovators, whether they were involved in all types of innovations or only in radical innovation. In terms of the question of what problems are faced by firms wishing to innovate, the study found that firms perceived technical obstacles as the most difficult to surmount, although marketing and financial obstacles were also seen as important. Indeed, the perception of the importance of these obstacles was significantly higher for radical innovators than for non-innovators. Innovators, particularly radical, and non-innovators, have a very different understanding of what it entails to innovate.

Will China's position in world innovation change? Will firms in China be able to engage in radical innovation for the world? Will China become a technological superpower? Barring a major resource or environmental crisis, most likely – particularly if present growth trends continue, but it will take some time. Getting to today's position has already taken around 25 years and there are yet a number of "structural" transformations to be made. There is still some way to go in terms of international standards, range of products, depth of knowledge and structure of firms, e.g. increasing the number of small innovative firms. Technical and marketing skills also need to be learned properly. More importantly, the Chinese market, to which most of the present innovations are orientated, will still remain an important source of demand, one that in itself can justify new products and processes for a significant period of time. On the one hand, it will be a matter of extending the market across China, something that will probably not require significant technical change beyond what can be achieved through imitation. On the other, as the market in more advanced regions expands, it will also grow in sophistication, leading to more and more complex innovations that may gradually result in a narrowing technological gap with developed countries. Tensions will arise between these two processes, which will demand time in sorting out.

Innovating for the world will also require the intense participation of foreign firms, who, after all, account today for a major share of Chinese innovation aimed at the world. It is difficult to see major multinationals easily giving up their most advanced technology and "crown jewel products" for research and development in China. Even if they did so, the transfer process will also take some time. In sum, while the international catching-up process could easily take several decades, the seeds for a sustained innovation process seem to be in place.

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Notes

[1] We are grateful to an anonymous referee for pointing this out.

[2] In China, between 1998 and 2002, the proportion of state, collective and co-operative industrial firms fell from around 75% to 43%; the proportion of non-mainland and foreign firms increased from 16% to 19%; while the proportion of other forms of ownership increased from 9% to 39% (NBS, 2003).

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