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A Survey for Technological Innovation in Taiwan

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Abstract: Statistical data on R&D development in Taiwan has been formally incorporated into the OECD/MSTI database (Main Science and Technology Indicators). Our surveys and analysis of R&D activities are clear and complete. However, the mode of development of the knowledge economy development, aside from the R&D activities themselves, depends on the production, circulation, and application of knowledge and/or technology. Direct relationship between the new knowledge produced by R&D activities and industrial sector products or manufacturing process innovations is difficult to visualize. R&D activities are high in risk, their outcome uncertain; there is no assurance that investment in R&D will yield innovative products for the marketplace. By contrast, enterprises without any investment in R&D activities can still bring out products that are new in technology.

Thus, the EU began for the first time to develop Community Innovation Survey (CIS) in the 90's. The main goal was to collect data on how enterprises in different countries invest in the technology innovation process, and on the products of this process. The results of the analysis of such surveys can make contribution to the development of innovation policies and to the spread and transfer of new technology. The industrial structure of Taiwan is composed mainly of small and

medium-size enterprises, accounting for 98% of all enterprises. Major R&D activities is concentrated in larger organizations, as the 300 largest domestic enterprises account for about 70% of R&D activity spending. According to the results of the first Taiwan Technological Innovation Survey (TTIS I), in the three years from 1998 to 2000, overall 50.2% of business enterprises engaged in technology innovation activity. In this survey, the definition of "technology innovation activity" of the Organization for Economic Cooperation and Development (OECD) was used (for enterprises with over 20 employees, the results were weighted according to the number of enterprises in a stratum). The figures for the manufacturing sector and service sector were 51.1% and 49.3% respectively.

Looking at the results weighted for number of employees, in the three years from 1998-2000, for all enterprises with 20 employees or more, approximately 63.7% of employee had engaged in technology innovation activity; the figures for the manufacturing and service sectors were 68.3% and 58.6% respectively.

For funds spent on innovation activity, in the year 2000, the total invested by enterprises with 20 employees or more was approximately 563.86 billion NT$, which accounted for 2.81% of the total revenues of these enterprises. This is an underestimate. Looking specifically at the manufacturing sector, technology innovation activity spending accounted for 4.08% of revenues, versus 1.84% for the service sector.

As for constraints on innovation, or factors hampering innovation, the most important factor was the lack of appropriate technology and the percentage of R&D employee. The second most important factor was excessiveness of economic risk. Most of an enterprise's main information sources come from customers or consumers; the next most important was the internal part of the company.

Key words: technological innovation survey, technology innovation activity, R&D.

1. Introduction

Knowledge drives economy. Knowledge and innovation have become the most powerful tools for strengthening national competitiveness. Increas-

ingly knowledge-based economy, technological innovation — the capacity to apply new knowledge to improve productivity and create new products and services — is more significant than ever. This capacity relies not only on scientific inventiveness and entrepreneurial flair but also, critically, on the conditions, which permit, encourage and sustain the innovative creativity, or restrict it, Silja Kurik *et al.* (2002).

Statistical data on R&D development in Taiwan has already been formally incorporated into the OECD/MSTI database (Main Science and Technology Indicators). Such data mainly describes R&D spending, manpower, and other resource investments. Accommodating statistical data on other achievements such as patents, doctoral theses, etc., is often used in order to compare the levels of technology of different countries. Such data is also an important basis used by each country in drafting important policy. Since the early period, R&D activities have been emphasized internationally, and there has already been 30 years of research conducted on such activities. Taiwan's Nationwide Survey on Technology and Science Activity has also been held for over 20 years. Our surveys and analysis of R&D activities are clear and complete (National Science Council Executive Yuan, 2002). However, as to the mode of development of the knowledge economy development, aside from the R&D activities themselves, depends on the production, circulation, and application of knowledge and/or technology. Yet the direct relationship between the new knowledge produced by R&D activities and industrial sector products or manufacturing process innovations is still to be characterized . R&D activities are high in risk, their outcome uncertain; there is no guarantee that investment in R&D will yield innovative products for the marketplace. By contrast, enterprises without any investment in R&D activities can still bring out products that are new in technology, Shia *et al.* (2002).

Thus, in the 1990s, the European Commission (EU) began for the first time to develop Community Innovation Survey (CIS). The main goal was to gather data on how enterprises in different countries invest in the technological innovation process, and on the outcomes of this process. The results of the analysis of such surveys can make a contribution to the development of innovation policies and to the spread and transfer of new technology.

In addition, the Organization for Economic Cooperation and Develop-

ment (OECD) has published the OSLO Manual with the EU, which serves as a reference handbook and standard for innovation surveys (Daniel *et al.*, 1997). At present, EU innovation surveys have been carried out to CIS III, and the data for individual countries is continuously being published. Furthermore, the EU is currently planning CIS IV. To obtain get internationally comparable results, the first Taiwan Technological Innovation Survey (TTIS I) was carried out in accordance with the EU-developed common methodology — CIS III. As a result, we can compare the innovation of enterprises in Taiwan and the economy as a whole with almost every other European country.

Taiwan's industrial structure is composed mainly small and medium-size enterprises, which accounts for 98% of all enterprises. Major R&D activities is concentrated in larger organizations, as the 300 largest domestic enterprises account for about 70% of R&D activity spending. R&D activities carry the most risk and are the least reliable of investments. Taiwan's industrial framework is dominated by SMEs (small and medium enterprises). Although such enterprises do not engage in elaborate R&D activities, many of them still introduce enhanced or completely new products to the market, showing that SMEs are actually quite innovation active. Technological innovation is an extremely important aspect of the development of the information economy. The Technological Innovation Survey provides an important indicator of this economy.

Various kinds of data have been gathered by TTIS I, this is an important survey and this article is the main technical report, for example, we now know about the application and flow of innovation knowledge in different types of enterprises, as well as about the recognition of and demand for innovation in the following sectors: SMEs, the science and technology industry, and traditional industry. A further body of data has been gathered on constrains on innovation projects and activity. The analysis of this survey data provides the government with a reference when setting science/technology and finance/economic policy.

2. Description of Survey Methodology

The process involved in technological innovation activities is kaleido-

scopic, from manufacturing process and product enhancement, new market development, the acquisition of new materials, the adjustment of marketing strategies, organizational management reform, and changes in packaging design. However, in the actual practice of surveys, clarity of definitions and classification schemes is needed. The OSLO Manual, innovation survey outlined by the OECD directorate, clearly sets the field of inquiry at technical innovation (product and manufacturing process enhancement). The main considerations are set as: measurability and the intimate relation between technical innovation and research development. The definition of technological innovation includes: (1) Bringing to market products that are technologically new for the company, or which represent significant improvements in technology; (2) Implementing technologically new or greatly improved manufacturing procedures. As for other non-technological activities — such as strategy, organizational adjustment, product packaging texture and art design, marketing methods, etc. innovative activities — although they help to expand corporate revenue, they are not included in the field of Technological Innovation Surveys because they are excluded by the measurement methodology.

2.1 Survey profile

1. Scope and Time Frame

Period of administration: August 1, 2001 to July 31, 2002. This survey included two stages, which were the telephone selection stage and the interview stage. The range of the survey was Taiwanese enterprises with more than 6 employees, including both the manufacturing sector and the service sector.

2. Subjects

The survey subjects were high-level directors at the level of manager or Vice GM or above, or their authorized employee.

3. Design

(1) Survey Population

The enterprise data contained in the 2000 Industry and Commercial Census of the Directorate-General of Budget, Accounting and Statistics (Executive Yuan) formed the population records.

(2) Sampling Methodology

This survey is in accordance with the standard classification of industries in Taiwan's existing developmental surveys, and with OECD's standard classification of industries. Each industry is further tiered according to enterprise size (i.e., number of employees). Employee numbers were analyzed into the following five categories: 6-19, 20-49 , 50-249, 250-499, and over 500.

Then approximately 60,000 enterprises were selected — using the principles of stratified random sampling — from the population of the Directorate-General of Budget, Accounting and Statistics (Executive Yuan)'s Industry and Commercial Census. Among these, 10,000 enterprises were proper samples, while the other 50,000 were reserve samples.

(3) Survey Methodology

For enterprises with 6-499 employees, the telephone selection method was first used to inquire whether in the period from 1998-2000 enterprises had been innovation active. For all that had, the second stage was interviewing. For those enterprises without technological innovation, a portion was selected for face-to-face interviews, in order to clarify the proportion of innovation inactive companies to innovation active companies. This is represented in the lower right part of Supplementary Figure 1, in the frame with dotted line. Through the telephone selection survey, successful interviews were conducted with 7,689 enterprises, and among these 2,738 were innovation active enterprises while 4,951 were innovation inactive enterprises. For large-scale enterprises with more than 500 employees, the questionnaire was first sent by mail, and then employee were sent out to conduct a census-style survey in an interview setting. In total, this process was completed for 506 enterprises. In addition, during the telephone selection survey, there were 4,951 enterprises that gave the response that they were not engaged

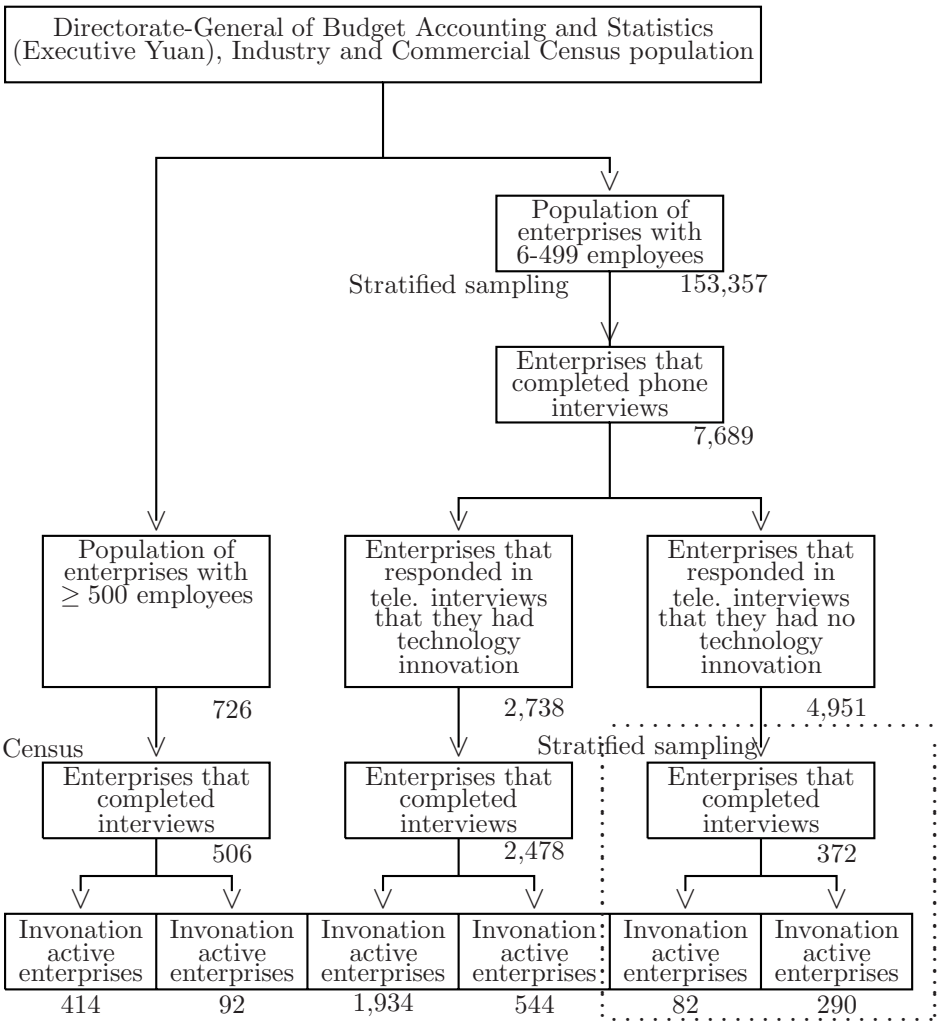

Figure 1: Flow chart for the First Technology Innovation Survey of Taiwan

in technological innovation. Next stratified random sampling was used to

select samples, and successful interviews with in total 372 enterprises were completed.

2.2 Structure of the interview samples

The status of the actually completed interviews is shown in Supplementary Table 1 below. There were a total 3,356 of valid interview samples, including 2,430 innovation active enterprises and 926 innovation inactive enterprises. Among the companies with such activity, 2,016 had employee numbers from 6-499, while 414 had over 500 employees. Among companies without such activity, 834 had from 6-499 employees, while 92 had more than 500 employees. In these figures, one item that deserves our attention is the there were in total 726 large enterprises with more than 500 employees, which means that 220 organizations did not respond. One of the reasons for the non-response is that these large corporations felt that this Technological Innovation Survey would touch upon treading secrets, so they were not willing to be interviewed. This resulted in our being unable to acquire complete data when estimating spending on technological innovation activity. Thus, Taiwan's overall enterprise spending on technological innovation activity is underestimated.

Table 1: Valid Interview Samples-General Composition

	6-499 employees			Over 500 employees			
	(a)	(b)	Subtotal	(a)	(b)	Subtotal	Total
Innovation active	1,117	899	2,016	257	157	414	2,430
Innovation inactive	248	586	834	23	69	92	926
Subtotal	1,365	1,485	2,850	280	226	506	3,356

(a)= Manufacturing sector, (b)= Service sector

3. Technological innovation Activity: State of Affairs

In order to compare Taiwan with other countries, we treat the industrial structure of Taiwan in accordance with the OECD's classification standards, dividing enterprises into three categories with respect to their number of employees: 20-49, 50-249, and over 250. In this manner, we will investigate the status of technological innovation activities in Taiwan.

3.1 Domestic enterprise technological innovation activity — Enterprises with over 20 employees

"Innovative Active Enterprises" include those that have successfully brought out technologically innovative products or have implemented technological innovations in manufacturing procedure. This category also includes enterprises that have "incomplete innovation projects."

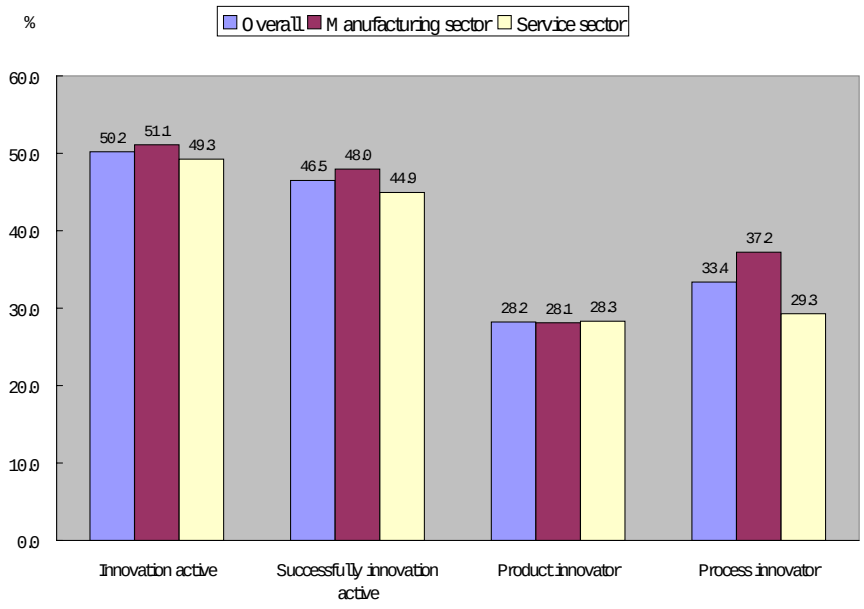

Figure 2: Enterprise technological innovation activity — over 20 employees. Source: TTIS I-1998-2000 database

According to the results from TTIS I, in the three years from 1998 to 2000, approximately 50.2% of Taiwan enterprises with over 20 employees were innovation active. The proportions for the manufacturing sector and service sector were respectively 51.1% and 49.3%. For successful technological innovations alone, approximately 46.5% of enterprises were successfully innovation active. The proportions for the manufacturing sector and the service sector were respectively 48% and 44.9%. Consult Figure 2. In addition, it was also learned that approximately 28.2% of enterprises were successful product innovators; the level of success in the manufacturing sector and the service sector was about the same, 28.1% and 28.3% respectively. From the perspective of bringing manufacturing process innovations into use, approximately 33.4% of enterprises were process innovators. The proportions for the manufacturing sector and the service sector were 37.2% and 29.3% respectively. Thus, it is clear that the two sectors are almost equal in terms of product innovation, but that for process innovation, manufacturing was higher than service by 8 percentage points.

3.2 Participation by enterprise employee in technological innovation activity — Enterprises with over 20 employees

In discussing the status of technological innovation activities, in addition to the original proportional number of enterprises, the data will be weighted for the number of employees at each enterprise. The objective is to avoid looking at large-scale and small-scale enterprises with the same emphasis. In fact, there is a proportional relationship for investment in technological innovations when one compares large-scale organizations with small-scale enterprises. This is to say that since large enterprises have more employee, there are relatively speaking a greater number of employees participating in technological innovation activities. Of course, they will also invest more funds in such activities. Thus, weighting the data for the number of employees is better able to truly reflect the status of enterprise participation in technological innovation activities Regarding employee participation in technological innovation, in the three years from 1998-2000, among enterprises with 20 or more employees, about 63.7% had been innovation active. The figure for the manufacturing sector was 68.3%, while that of the ser-

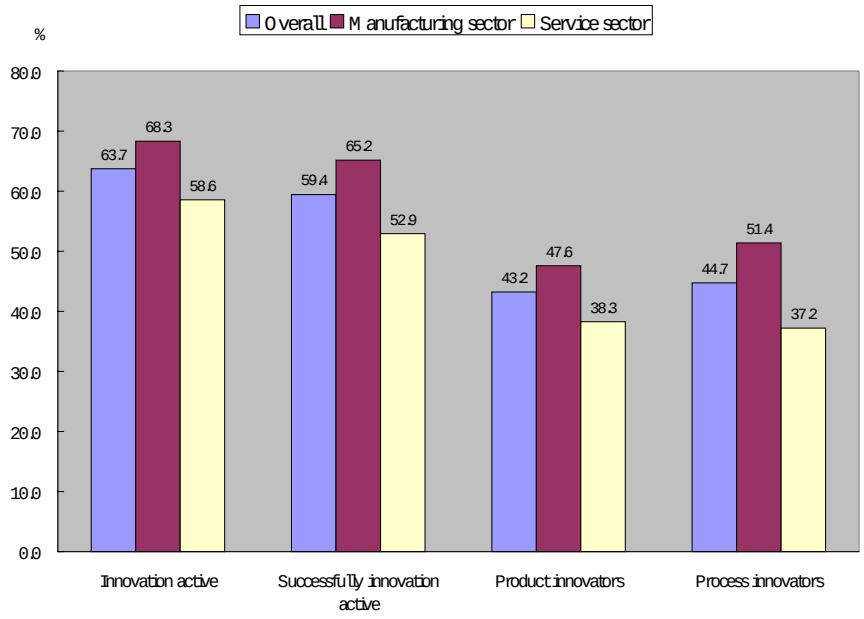

Figure 3: Enterprise employee participation in technological innovation activity — over 20 employees. Source: TTIS I-1998-2000 database

vice sector was 58.6%. As for the successful technological innovation, about 59.4% of enterprises were successfully innovation active, 65.2% in the manufacturing sector compared with 52.9% for the service sector. After detailed analysis, it was found that 43.2% of companies had brought technologically innovative products to market, about 47.6% in the manufacturing sector versus 38.3% in the service sector. Another perspective is implementing technological innovations in the manufacturing process. Overall, 44.7% of enterprises are process innovators, about 51.4% in manufacturing and about 37.2% in service. The results described above showed that the percentage of manufacturing sector process innovators was higher than the percentage of product innovators by 4 percentage points. In the service sector, on the other hand, the two categories were almost equal. Overall, the manufacturing sector was higher than the service sector for both categories. Consult

Figure 3.

3.3 Enterprises creating websites and e-business — Enterprises with over 20 employees

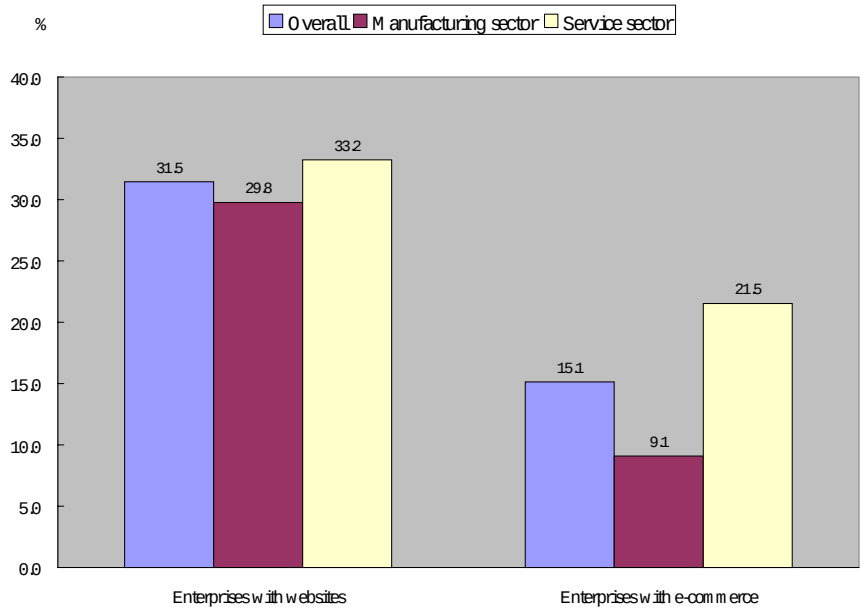

Figure 4: Overall enterprise website creation and E-business — over 20 employees. Source: TTIS I-1998-2000 database

In the three years from 1998-2000, for enterprises with 20 employees or more, about 31.5% had created company websites with company or product information (including both merchandise and services). The figures for the manufacturing sector and the service sector were 29.8% and 33.2% respectively. Overall, the percentage of manufacturers with websites was lower than in the service sector by 4 percentage points. Looking at e-commerce, among enterprises with 20 employees or more, about 15.1% had begun selling products (including merchandise and services) on the Internet. The

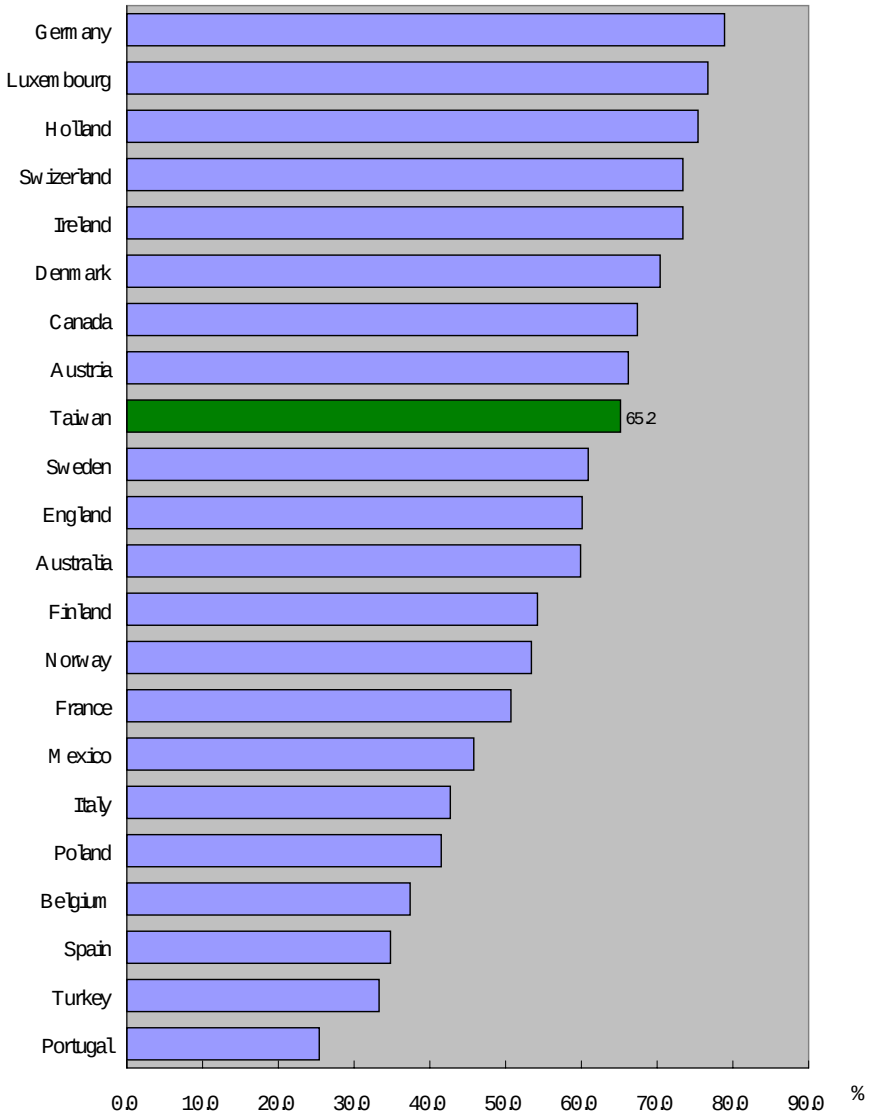

Figure 5: Successful technological innovations in the manufacturing sector by country. Source for data in Taiwan: TTIS I (1998-2000), the data is for manufacturers with over 20 employees. The results are weighted according to number of employees. Source for other countries: OECD Science, Technology and Industry Scoreboard , 2001.

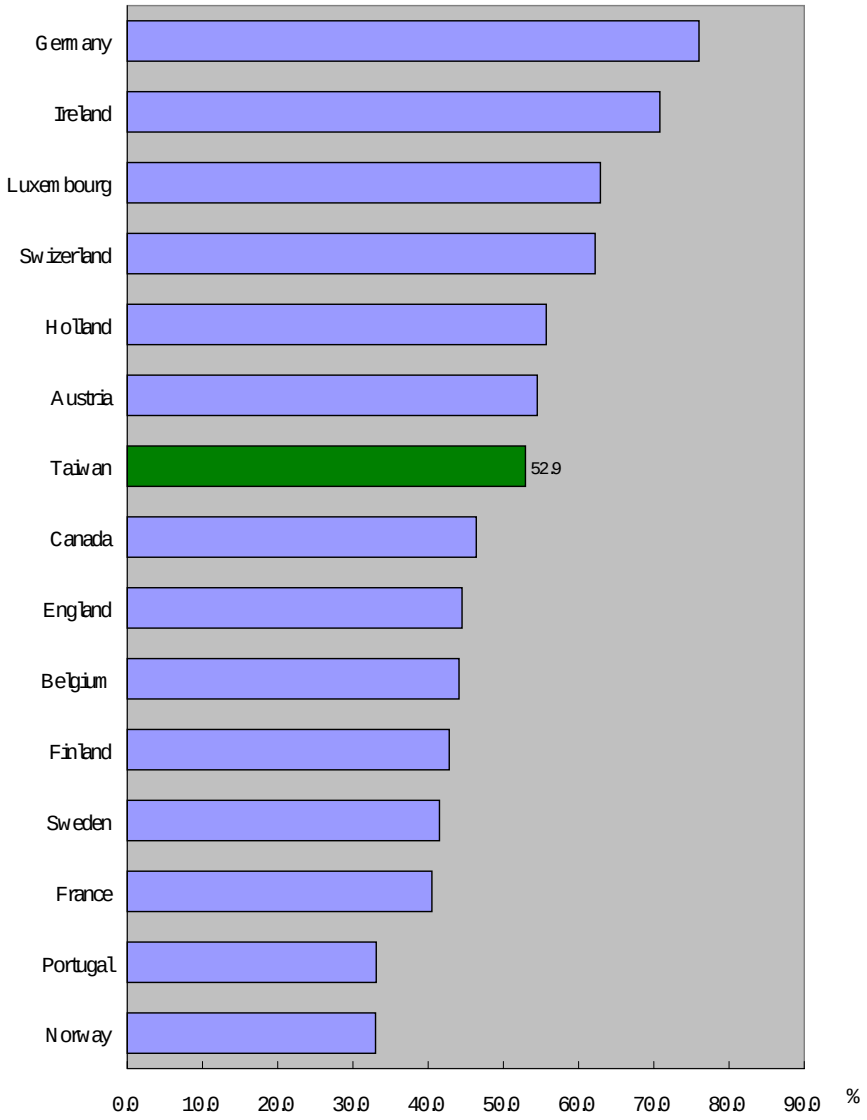

Figure 6: Successful technological innovations in the service sector by country. Taiwan data sources: TTIS I (1998-2000), the data is for manufacturers with over 20 employees. The results are weighted according to number of employees. Data source for other countries: OECD Science, Technology and Industry Scoreboard, 2001.

figure for the manufacturing sector was 9.1%, while the service sector was 21.5% of enterprises. Consult Figure 4.

3.4 Main national technological innovation successes — According to the OECD STI (science, technology, industry) scoreboard

3.4.1 Successful technological innovation by Country — Manufacturers with over 20 employees

It can also be observed that among all countries, the one with the manufacturing sector with the highest percentage of successful technological innovations was Germany, which had a figure of about 78.9%. The lowest figure was for Portugal — 25.4%. Taiwan was in an above average position with a figure of 65.2% [1], about the same as Austria (66.2%) and slightly higher than England (60.1%) and France (50.7%). Consult Figure 5, OECD Science, Technology and Industry Scoreboard (2001).

3.4.2 Major Countries-Successful Technological innovations for Service Enterprises with over 20 Employee

Overall, Germany's percentage of enterprises in the service sector with successful technological innovations was the highest at 76.0%. Norway was the lowest at 33.0%. For Taiwanese service sector enterprises with successful technological innovation, the figure was about 52.9%, right in the middle of the ranking; this figure is very close to Austria (54.5%) and rather higher than England (44.5%) and France (40.5%). See Figure 6.

3.5 Comparison of technological innovation activity by country

EU innovation surveys have already been carried out to CIS III, and the data for individual countries is continuously being published. Overall, Taiwan (50%) was second only to Germany, (Janz, *et al.*, 2002)[2] with other countries between 40% and 50%. Looking at business sector, the percent-

[1] The data from TTIS I (1998-2000),weighted by number of employees.
[2] TTIS I is Comparison of Technological innovation Activity by Country.

age of enterprises with innovation activity was higher in the manufacturing sector than in the service sector by from 3 to 6 percentage points, not a large difference; with the exception of Finland, the figure for manufacturing sector innovation was higher than service sector innovation by almost 11 percentage points.

4. Participation in R&D Work by R&D Employee in Innovation Active Enterprises

4.1 Participation of employee in R&D work — Analysis by size of enterprise

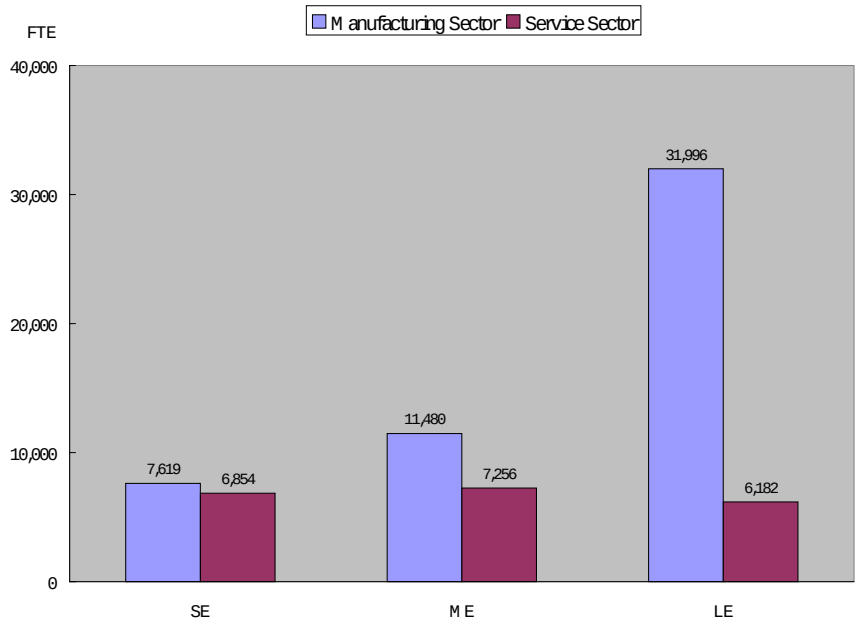

Figure 7: Participation of employee in R&D Activity at the End of 2000 — by the size of enterprise. Source: TTIS I-1998-2000 database

Proceeding to examine the relationship between enterprise size and the

number of employees participating in R&D work, one finds that in small enterprises (20-49 employees), the difference in participation numbers between the manufacturing and service sectors is actually small. For medium sized enterprises (50-249 employees), there is a clear difference in participation numbers between the two sectors, amounting to approximately 4,000 full time equivalents FTEs[3]. For large enterprises (over 250 employees), there is a large difference between participation numbers in the manufacturing sector and the service sector; the difference between them is that the manufacturing sector tops the service sector by a factor of five — see Figure 7. For the most part, participation numbers in R&D work in the manufacturing sector were higher than in the service sector, and the differential between the two sectors increased with enterprise size.

5. Hampering Factors and Information Sources of Technological Innovation Activities

5.1 Hampering status and factors of technological innovation activities

According to survey results, in the three years from 1998-2000, for companies engaging in technological innovation, approximately 46.7% experienced some form of delay. The differential between the manufacturing sector and the service sector was not large, with both about 47%. As to the percentage of companies that had to abandon technological innovation activity because of some problem, the overall figure was 29.1%. The service sector had a higher percentage of stoppage than the manufacturing sector, respectively 32.4% and 26.7%. See Figure 8. Inquiring into the reasons for these problems, one discovers that (Figure 9) in the three years from 1998 to 2000, among the factors that led to a serious delay of technological innovation activity, a lack of appropriate and qualified technology or R&D personnel was the highest at about 44.1%. The next most serious was excessive perceived economic risks, at about 27.6%. The difference between lacking market information and organizational rigidity was not large. The

[3]FTE:full time equivalents

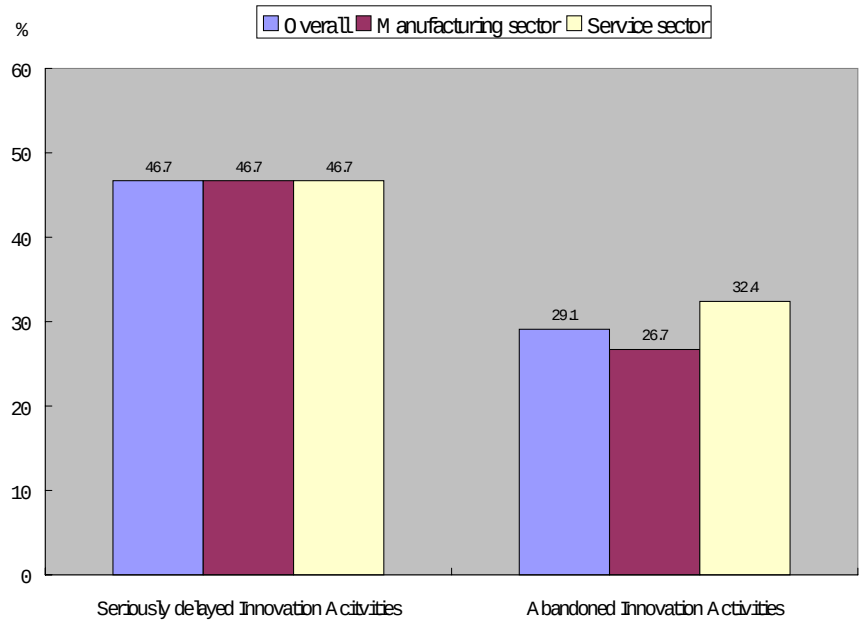

Figure 8: Hampering status of technological innovation activities. Source: TTIS I-1998-2000 database

least common factor was that competitors had already brought out a similar service or there was fear of encroaching on another's rights, at about 11.0%. Similarly, the main factor involved in abandoned innovation because of some problem was a lack of appropriate and qualified technology or R&D personnel, accounting for about 51.8% of the total. The next most important factor was excessive perceived financial risk, about 46.9%. The least common factor was the insufficient flexibility of regulations or standards, about 13.0%[4]. Thus it can be seen that the most common factor involved in hampering technological innovation activity was a lack of appropriate and qualified technology or R&D personnel. If this problem could be solved, the willingness of enterprises to engage in technological innovation could

[4]Hampering Factors of Technological innovation Activities is raw data without weighted

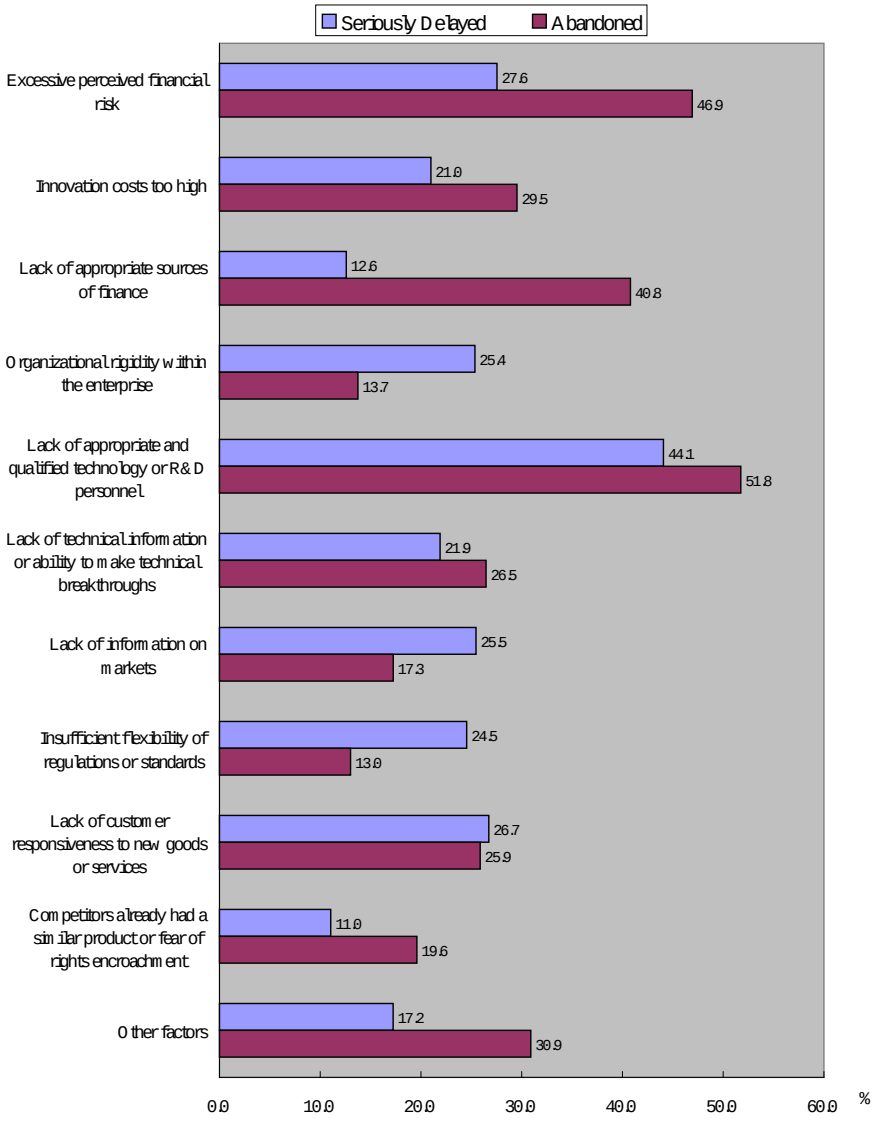

Table 9:Hampering factors of technological innovation activities. Source: TTIS I-1998-2000 database

be raised, and it should be possible to greatly raise the rate of success of technological innovations.

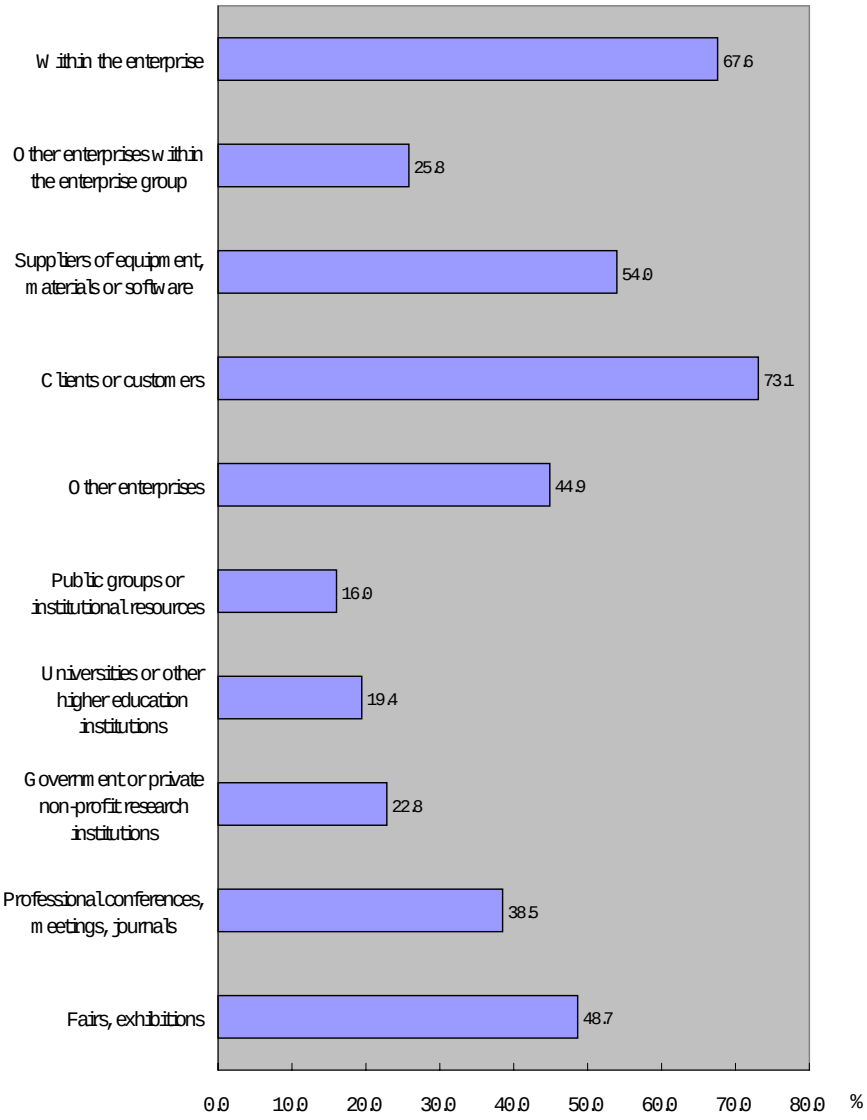

Figure 10: Information Sources for technological innovation activities. Source: TTIS I-1998-2000 database.

5.2 Information sources for technological innovation activity

In a discussion of innovation active Taiwanese enterprises, the major source of information was customers and consumers (73.1%). The next most important source of information was within the enterprise (67.6%). The third was the suppliers of equipment, materials, or software (54.0%). From this it is known that the information supplied by customers or consumers is precious, to the point of being more important than internal information sources. Relatively speaking, the least information was provided by universities or other higher educational institutions (19.4%) or by public institutions or conferences (16.0%)[5]. It can be seen that in enterprises with technological innovation, the most important source of information comes from customers or consumers, and the least important information sources are academic institutions.

6. Conclusion

According to TTIS I results, in the three years from 1998 to 2000, among Taiwan enterprises with over 20 employees (according to the OECD definition, weighted according to number of enterprises within each stratum), approximately 50.2% were innovation active enterprises. The proportions for the manufacturing and service sectors were 51.1% and 49.3% respectively. In terms of the results weighted for the number of employee employed at an enterprise, in the three years from 1998-2000, in Taiwanese 20+ employee enterprises, about 63.7% of employee were engaged in technological innovation activity. The figures for the manufacturing and service sectors were 68.3% and 58.6% respectively. Successful technological innovation activity can be divided into product innovation and process innovation. Among all Taiwanese enterprises, 28.2% are product innovators, while 33.4% were process innovators. These figures are much higher than for England, where the proportions of enterprises are 18% (products) and 15% (process) respectively. This reveals that the performance of Taiwan's SMEs is superior to England in both categories. This shows that Taiwan's technological innovation ability has reached a certain standard internationally. As for factors

[5]Information Sources for Technological innovation Activity is raw data without weighted

hampering technological innovation activity, the largest problem was a lack of appropriate and qualified technology or R&D personnel; next was excessive economic risk; as most of an enterprise's main information sources come from customers or consumers, the next most important was within the enterprise. In TTIS I, we have established a process for the TTIS to follow in the future. Included in this process are matters to pay attention to when designing a questionnaire, sampling and survey methods, safety problems that need to be considered in data analysis. We have thus drafted a complete and integrated research program. Through this survey, a knowledge base and a source of information related to domestic concerns can be reestablished. Furthermore, many kinds of data were acquired through TTIS I-such as the application and flow of innovation knowledge in different kinds of enterprise; demand for and recognition of technological innovation in SMEs, in the science and technology industry, and in traditional industry; and the different constrains on technological innovation activity. This data provides the government an important reference when setting science/technology and finance/economic policy.

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