UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT

Measuring the impact of ICT use in business

THE CASE OF MANUFACTURING IN THAILAND

Prepared jointly by the UNCTAD secretariat and the Thailand National Statistical Office

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Executive summary

The report is the outcome of a joint project of UNCTAD with the National Statistical Office (NSO) of Thailand which builds upon the measurement of information economy statistics to enable the assessment of the economic impact of information and communication technology (ICT). This is one of the first studies to use official developing-country data to measure the productivity impact of ICT use in business. The project is part of UNCTAD's capacity-building programme on measuring ICT to help developing countries to improve the production and quality of their ICT statistics at the level of firms through an international "Partnership on Measuring ICT for Development". These data and the ensuing analysis on measuring the economic impact of ICT use aim to provide policymakers with better tools to design, monitor and evaluate their ICT strategies.

Information and communication technologies have received particular attention in Thailand as enablers of economic and social development. In the context of the national ICT plan, the NSO has collected a large amount of data on ICT use through its annual ICT surveys of the business sector, ICT household surveys and surveys of specific industries such as manufacturing and services.

This report shows a detailed analysis of trends in ICT use by the Thai business sector by looking in particular at the use of computers, the Internet and the web. This is done against the background of a continuous increase in the proportion of businesses using ICTs in Thailand. The study also reviews the specialized literature estimating the productivity impact of ICT use at the firm level in a number of developed countries. It then presents the results of the empirical analysis measuring the impact of ICT use on productivity in manufacturing firms, both at a general level and also by geographical region, industry branch, firm age and size.

The results indicate that the use of basic ICTs such as computers is important to firm productivity, particularly in countries where a significant proportion of businesses are still not using computers. The analysis also finds that, in addition to computer presence, Internet use and web presence are also reflected in higher labour productivity. The study shows that small and newly founded manufacturing businesses, especially the ones located in the north and north-east of the country, should receive more support both in terms of facilitating their access to ICTs and in terms of information campaigns on how ICTs can help to increase productivity, improve the quality of products and better respond to demand. Technical information on how businesses implement ICT solutions can provide additional guidance to set industry-specific ICT strategies.

1. Introduction

Thailand's ICT strategy and policy

For more than a decade, the Government of Thailand has considered information and communication technology (ICT) an important enabler for economic and social development and for enhancing the competitiveness of domestic businesses. The establishment of the National Information Technology Committee in 1992 was one of the first high-level policy initiatives to promote ICT for development. The committee was chaired by the Prime Minister and had members from both the public and private sector (Thuvasethakul and Koanantakool, 2002).

Currently, Thailand's national ICT policy is based on the ICT Master Plan 2002-2006, which is part of the broader National Information Technology Policy Framework 2001-2010 and the Ninth National Economics and Social Development Plan. Government agencies, representatives of the private sector, civil society and academia participated in the debate leading to the adoption of the ICT Master Plan. Since 2002, the Ministry of ICT has been in charge of pursuing and implementing the objectives and strategies set out in the Master Plan. The Master Plan had the general goal of fostering Thailand's development through ICT and focused on four main objectives: to increase the country's economic competitiveness; to develop a knowledge-based society; to foster sustainable development through equitable access for all; and to develop the ICT industry (NECTEC et al., 2003). Currently, the Ministry of ICT is in the process of preparing the second National ICT Master Plan for the next five years (2007-2011).[1]

Measuring statistically the access to and use of ICTs has become an important element of the Thai national ICT policy. Producing ICT indicators is considered key to monitoring and assessing progress in the implementation of national ICT plans, to compare ICT developments in Thailand with those in other countries and to help in future policy making (Smutkupt and Pooparadai, 2005). As established in the national ICT plan, the National Statistical Office (NSO) of Thailand is responsible for producing the necessary ICT data, conducting surveys and carrying out relevant analysis. The first ICT household survey dates back to 2001. In its 2003 Manufacturing Industry and Business Services Surveys the NSO included a number of ICT indicators and since 2004, the NSO carries out an annual stand-alone ICT survey with businesses in Thailand's municipal areas.

Background and objectives of the project

The collaboration between UNCTAD and the Government of Thailand on ICT-related matters dates back to 2002, when the Asia-Pacific Regional Conference on "E-commerce Strategies for Development" was held in Bangkok, under the auspices of the Thai Government. Since then, UNCTAD has been cooperating closely with the Government in the area of ICT for development, mainly through NECTEC (National Electronics and Computer Technology Center).

Cooperation on ICT statistics started in 2004, when UNCTAD began its annual data collection on ICT in business and the ICT sector. Since then, UNCTAD has been actively assisting developing countries to improve the production and quality of their ICT data. In the context of the Partnership on Measuring ICT for Development,[2] which was launched in 2004 at UNCTAD XI in Brazil, UNCTAD has developed a capacity-building programme on ICT measurement that

[1] Policy Statement by Mr. Kraisorn Pornsutee, head of Thai delegation to the ITU Plenipotentiary Conference in Turkey, 2006, http://www.itu.int/plenipotentiary/2006/statements/thailand/index.html.
[2] For more information see http://measuring-ict.unctad.org.

includes the delivery of training, courses and workshops, advisory services to countries and the publishing of a methodological "Manual for the Production of Statistics on the Information Economy".

Measuring the impact of ICT using firm-level data has received increasing attention recently, particularly by NSOs in OECD countries, which have carried out firm-level analyses on the impact of ICT use on labour productivity using microdata (see section five). Based on the research approach applied in such studies, UNCTAD in collaboration with the Thai NSO carried out a research project to measure the impact of ICT use on labour productivity in Thai manufacturing firms.

The objectives of the project were two-fold:

First, the project aimed to assist the NSO build capacity in the analysis of ICT statistics by applying econometric modelling techniques. To start the project, in January 2007, UNCTAD provided a one-week training in Bangkok to staff of the NSO, on applying econometric techniques to ICT data analysis. This was followed by a period of in-depth data analysis by the UNCTAD ICT Policy and Analysis Unit, in close cooperation with the Economic Statistics Analyzing and Forecasting group of the NSO, during which further technical assistance was provided via long distance. The objective was to allow the NSO staff to replicate the analysis carried out in UNCTAD with a view to enable the NSO to apply similar analytical methods when new data become available.

Second, from a substantive point of view, the project aimed to study the link between ICT use in firms and labour productivity in a developing country setting. While previous studies on the productivity impact of ICT use in firms have been carried out in developed countries, this is one of the first comparable analysis based on official statistics from a developing country.[3] Several recent studies[4] highlight the need to study the way in which ICT use by the business sector translates into greater economic efficiency. Businesses investing in ICTs do not necessarily acquire long-term competitive advantage positions, while those not investing in ICT are almost certain to find themselves at a disadvantage in the market. Ultimately, higher gains from ICT depend increasingly on identifying the efficient ways of using these technologies. Accordingly, the Partnership on Measuring ICT for Development encourages research on estimating the economic impact of ICT, and UNCTAD in particular has engaged in helping developing countries to use micro data for measuring the link between ICT use by businesses and their economic performance.

The report is structured as follows. First there is a short presentation of the main data sources and the methodology used for obtaining ICT statistics. Section three provides an overview of the use by Thai businesses of basic ICTs, such as computers, Internet and the web, comparing data from the 2004, 2005 and 2006 ICT Business Surveys. It also includes qualitative information on factors identified by businesses as barriers to ICT. Section four focuses on ICT use in manufacturing firms, the sector chosen for the productivity analysis. Section five presents the literature review and findings of studies on measuring the impact of ICT on labour productivity, followed by the theoretical framework for this study in section six. A verified empirical model (Cobb-Douglas production function) was used to quantify empirically the relationship between ICT uptake and productivity as well as to identify differences based on geographic location, industry sector, firm size and age in the Thai manufacturing sector. The Report concludes with a detailed presentation of estimation results and with the formulation of policy recommendations in sections seven and eight.

[3] For example, the Information for Development Programme (InfoDev) has launched in 2006 a project for measuring the impact of ICT use in Poland, Russia and the Baltic States (www.insme.info/documenti/InfoDevGlobalNet-web.pdf).

[4] For example, Atrostic and Nguyen (2005), Bloom, Sadun and van Reenen (2005) and Farooqui (2005).

2. Data and statistical methodology

The statistics presented in this report are mainly based on two types of data sources made available by the NSO of Thailand.

The *2004, 2005 and 2006 ICT Business Surveys* were used to produce descriptive statistics on ICT use in the Thai business sector. The surveys cover a reference period from April to March. Each of the three survey covers more than 77,000 businesses engaged mainly in manufacturing and services, including business trade services, construction, land transport and activities of travel agencies and hospitals. Only firms located in urban (municipal) areas were covered by these surveys. When information on a given indicator could be traced through the three ICT Business Surveys, the report showed a comparison between results of the 2004 and the 2006 Survey. Where data were not available, the report presents only data from the 2005 and the 2006 surveys.

The *2003 Manufacturing Survey* was used for carrying out the productivity analysis using econometric techniques. This dataset contains information on more than 8,800 manufacturing businesses located both in urban (municipal) and rural (non-municipal) areas, with reference period January - December 2002. In order to study the relationship between ICT uptake and economic output it was necessary to link ICT and economic variables, which was only possible with data contained in this Survey. The econometric study was therefore limited to the 2002 cross-section of Thai manufacturing firms. In the future, when more data will become available, a more complex analysis can be carried out in order to establish the impact of the past levels of ICT use on current economic performance.

The ICT statistics used in this research were collected by the NSO of Thailand through a stratified sampling method that took into account businesses of different employment[5] size, located in different geographical regions and from different industry branches. This method made it easy to keep track of businesses with different characteristics and of the share of each group within the whole business sector. Thus, all the descriptive statistics presented in this report have been transformed with the help of corresponding sampling weights in order to reflect the entire population of Thai businesses engaged in either services or manufacturing and with more than 10 employees. The comparison between the 2005 ICT Business Survey and the 2003 Manufacturing Survey focusing on manufacturing businesses only, also refers to firms located in urban (municipal) areas.

While both surveys include a large number of micro enterprises (with 10 or less employees), the data and results presented in this study only include firms with more than 10 employees. This approach allowed the study to focus on the performance of small, medium sized and large enterprises, which are producers of most revenues and value added. In Thailand, micro enterprises represent 94 per cent of all establishments in the market, but they have a small contribution to revenue, value added and employment. For example, in the manufacturing sector, firms with more than 10 employees represent only 8 per cent of the firms but account for 77 per cent of the employment, 98 per cent of the revenues and 96 per cent of value added. Similar characteristics can be found in other economies as well[6] and therefore usually research is conducted separately for the two categories of firms. While recognizing that a separate analysis studying the impact of ICT use on micro enterprises can also yield meaningful results for policymakers, this was beyond the scope of the project.

[5] Employment figures presented in this report refer to all employees, which include both paid and unpaid labour.

[6] For example 92 per cent of all European enterprises have less than 10 employees and they employ 34 per cent of the workforce. In the US (2000) as well 94.2 per cent of the firms present in the market are micro enterprises and they provide 21.5 per cent of the jobs (Eurostat, 2003).

3. Overview of ICT use in business

The Thai economy has experienced positive growth since 2001, with increases in both real GDP and real per capita GDP of respectively 5.6 and 4.8 per cent (CAGR) annually.[7] In 2005, the structure of the Thai economy expressed in GDP shares is composed of 43 per cent services, 37 per cent manufacturing and 10 per cent agriculture (World Bank, 2006). According to the Thai 2005 ICT Business Survey, 68 per cent of the business sector is made up of manufacturing, wholesale & retail trade, hotels, restaurants and the food shop industry. After the contraction suffered in connection to the 1997-1998 regional financial crisis, the volume of sales in the manufacturing sector rebounded already in 1999, grew slowly in 2000-2001 and registered record growth rates of 7.5 per cent annually in 2002-2006 (Economist Intelligence Unit, 2007). Strong domestic demand and a competitive position in the export markets have been important factors of growth in Thailand. The main manufacturing products exported are vehicles, electronics, electrical goods and textiles. Output in the electronics sector in particular has recorded 30 per cent annual average growth rate between 2002 and 2006, with two main types of products: integrated circuits and hard disk drives (HDDs). Thanks to the success of foreign investment promotion strategies global producers contribute with a high share to the output in this sector (UNCTAD, 2005). The computer and related service sector, although increasingly important in terms of sales, represented in 2005 only 1 per cent of the total number of firms with more than 10 employees.

The use of ICT in Thailand has expanded rapidly. According to NECTEC, the Internet started being used in 1987. By 1994, all state universities were on-line, and commercial Internet Service Providers started to operate in 1995 (NECTEC, 2003). Since then, the growth of ICT has been astounding. The 2005 ICT Business Survey revealed that among Thai businesses with more than 10 employees, 79.7 per cent use computers, 55.4 per cent have access to the Internet and 26.2 per cent have web presence (table 1).

Despite significant progress over the past years, ICT adoption in Thailand is still behind levels achieved in some Asian economies with higher per capita income, such as the Republic of Korea, Singapore and Hong Kong (China). In fact, as shown in table 1, 90.2 to 96.6 per cent of the enterprises in the three above mentioned economies were using computers and 84.4 to 95.9 per cent had access to Internet in 2005. Similar to these economies, Thailand has carried out efforts to produce and disseminate on a regular basis statistics on the use of ICT by businesses. This is indicative of the relevance placed by Thailand on the implementation and monitoring of ICT policies.

Table 1. Proportion of businesses with computers, Internet and web presence in selected Asian economies, 2005

2005	Proportion of businesses using computers	Proportion of businesses with access to Internet	Proportion of businesses with web presence
China	..	67.6	22.3
Hong Kong (China)	90.2	84.8	40.5
Republic of Korea	96.6	95.9	56.5
Singapore	92.8	91.0	68.3
Thailand	79.7	55.4	26.2

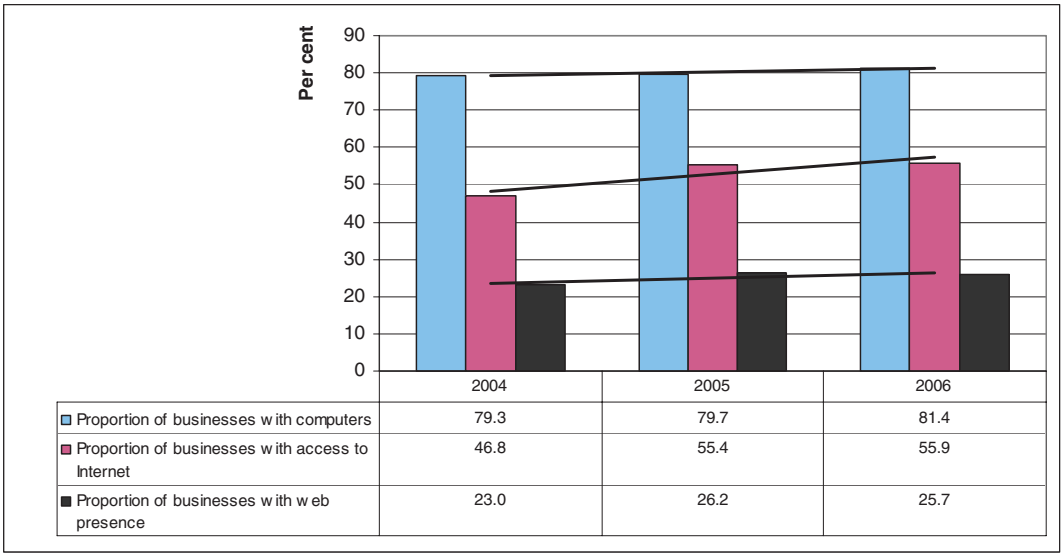
Note: Economies selected based on the availability of official statistics.
Source: UNCTAD information economy database, 2007, and the 2005 ICT Business Survey, businesses with more than 10 employees.

This section presents detailed information on the use of basic ICTs such as computers, the Internet and the web by Thai businesses. It draws mainly on data from the 2004, 2005 and 2006 ICT Business Surveys and covers only municipal (urban) enterprises with more than 10 employees, engaged in manufacturing and services activities.

[7] Data source UNDESA 2007.

Over the analysed period of time, the proportion of businesses with computers, access to Internet and web presence has increased slowly (chart 1). Improvements in the quality and price of Internet connections resulted in a considerably faster rise in the proportion of businesses with access to Internet than in the case of the other two technologies. The slightly smaller proportion of businesses with web presence in 2006 as compared to 2005 is related to a decline of 3 per cent in the number of large businesses with more than 200 employees present in the Thai market. The proportion of businesses with computers grew continuously over the three years by 1 per cent annually, thus increasing in three years by 3,346 the number of businesses with computers. The highest growth rate is found in the proportion of businesses with access to Internet.

Chart 1. Proportion of businesses with computers, Internet and web presence in Thailand, 2004-2006



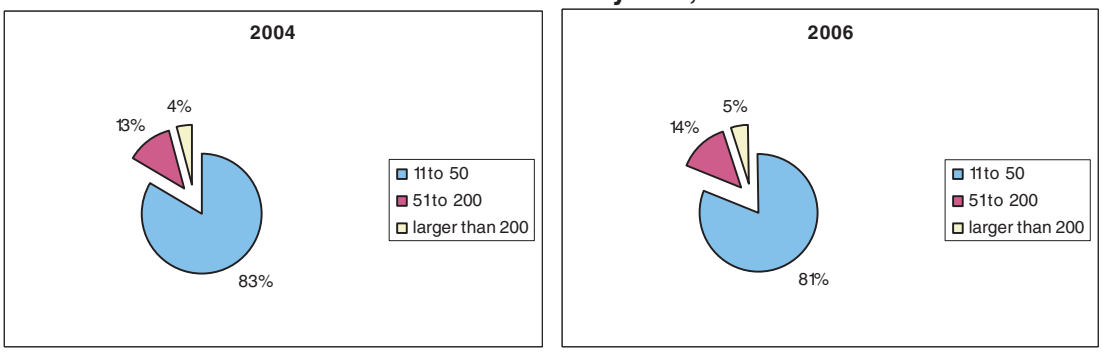
	2004	2005	2006
Proportion of businesses with computers	79.3	79.7	81.4
Proportion of businesses with access to Internet	46.8	55.4	55.9
Proportion of businesses with web presence	23.0	26.2	25.7

Source: 2004, 2005 and 2006 ICT Business Survey in Thailand, businesses with more than 10 employees.

General characteristics of the business sector

Small companies (11 to 50 employees) make up for the lion's share of the Thai market (chart 2), whereas middle-sized and larger firms represent the remaining one fifth of the businesses. From 2004 to 2006, the number of businesses in Thailand grew moderately from approximately 52,000 to 54,000. 2005 witnessed a significant pick up in the number of medium and large businesses with more than 50 employees. This tendency was reversed in the next year with a 4 per cent growth in the number of small businesses and a 3 per cent drop in that of large firms.

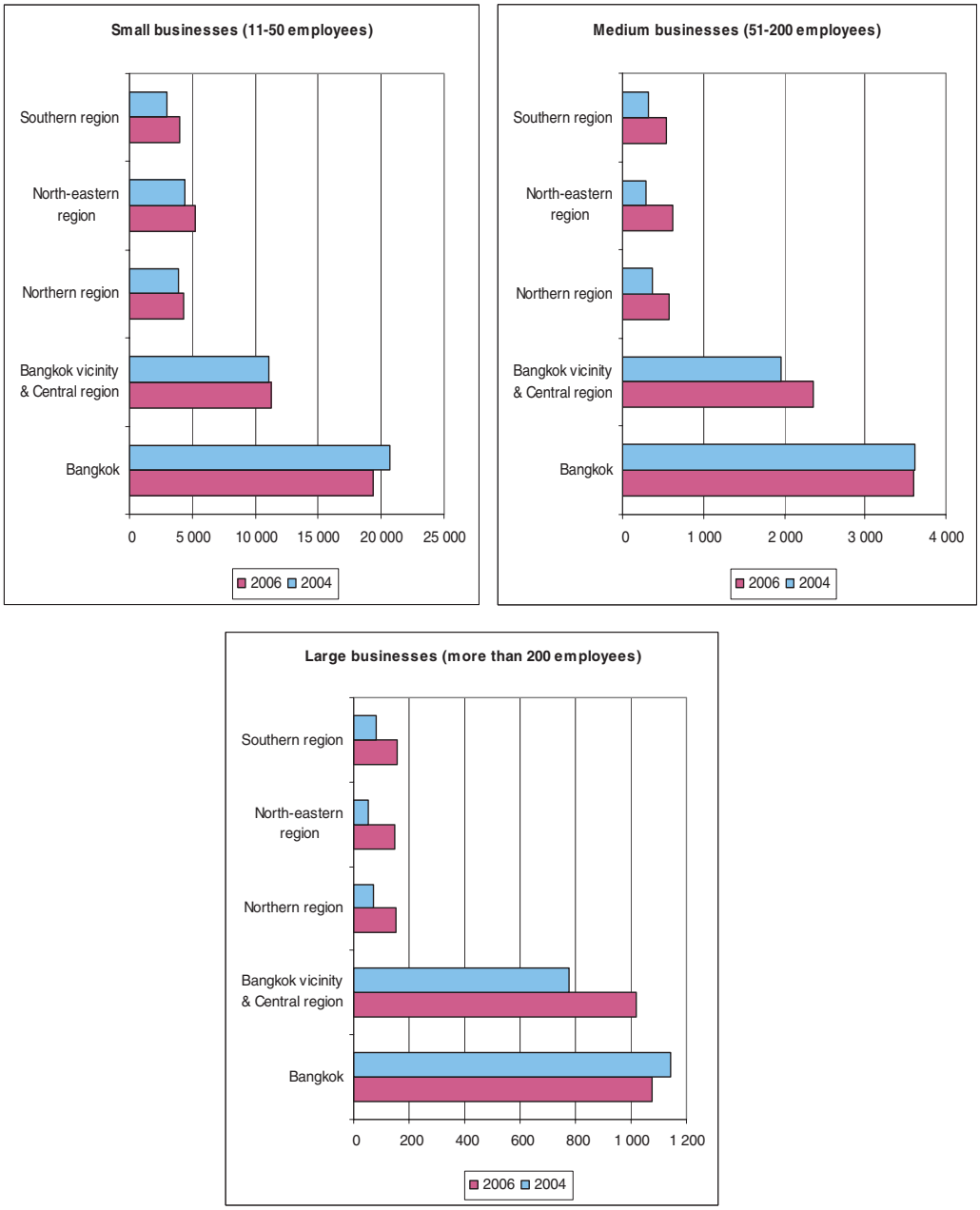
Chart 2. Thai businesses by size, 2004-2006



Source: 2004 and 2006 ICT Business Survey in Thailand, businesses with more than 10 employees.

Most enterprises are located in and around the capital region (chart 3). About three quarters of all municipal (urban) businesses are located in Bangkok, its vicinity and the Central region. These regions also have the highest concentration of large and middle-sized enterprises. Whereas 73 per cent of small enterprises are located in Bangkok, its vicinity and the Central region, this was the case for 77 per cent of the medium enterprises and 83 per cent of the large enterprises. Such concentration around the main municipal area is common in many economies and goes hand in hand with the advantages of operating in the main conglomerate. Conglomerates provide enterprises the possibility to benefit from, for example, cheaper and quicker diffusion of technology and from access to a greater number of consumers and potential employees. From 2004 to 2006, Bangkok's vicinity and the Central region showed the greatest increase in the number of businesses, particularly the large ones. The share of middle and large enterprises also increased in the northern, north-Eastern and Southern region over the same period of time, confirming a slight tendency towards a less geographically concentrated business sector.

Chart 3. Thai businesses by geographical region, 2004-2006



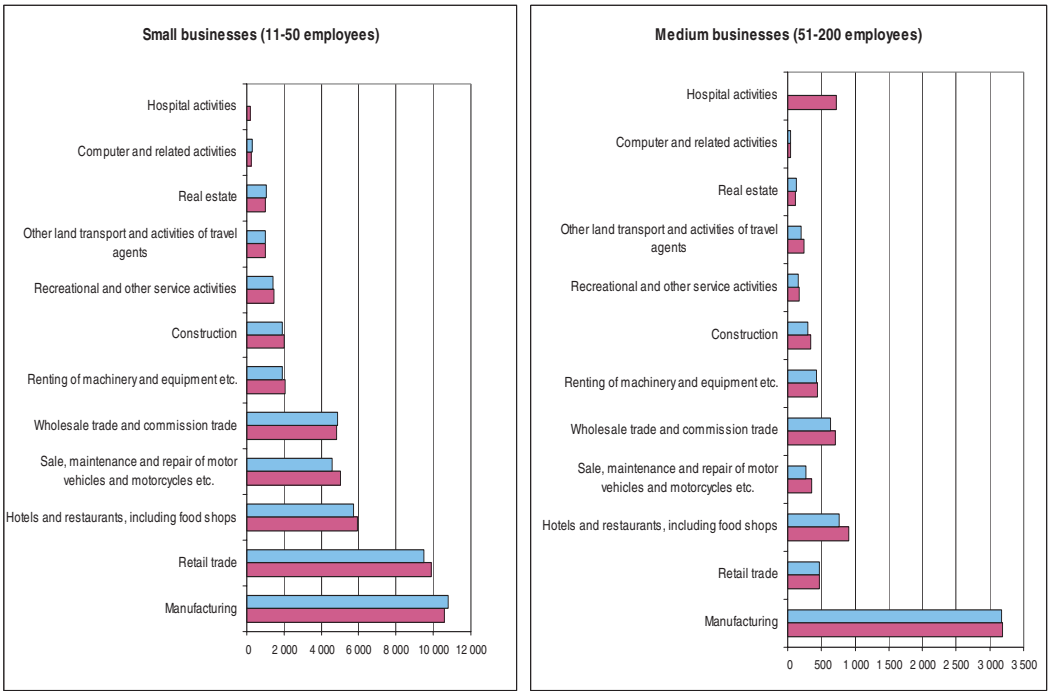
Source: 2004 and 2006 ICT Business Survey in Thailand, businesses with more than 10 employees.

There are four industries, which combined account for more than two thirds of the total number of businesses in Thailand[8]: manufacturing (29 per cent), retail trade (16 per cent), hotels and restaurants including food shops (12 per cent), and wholesale and commission trade (11 per cent). Industries differ in terms of average employment size of enterprises. There are many more large firms (more than 200 employees) in manufacturing and hospital activities, whereas in retail trade, wholesale and commission trade, hotels and restaurants small businesses are more dominant (chart 4).

There has been little variation in the number of businesses by main activity over the three years considered. The number of small businesses in wholesale trade, commission trade and retail trade has dropped, along with that of large businesses in the real estate and recreational service sectors. The manufacturing sector has seen an increase in the number of large enterprises over the three years. The concentration of large firms in specialized sectors of activity remained the same over time unlike shown before in the case of the geographical concentration.

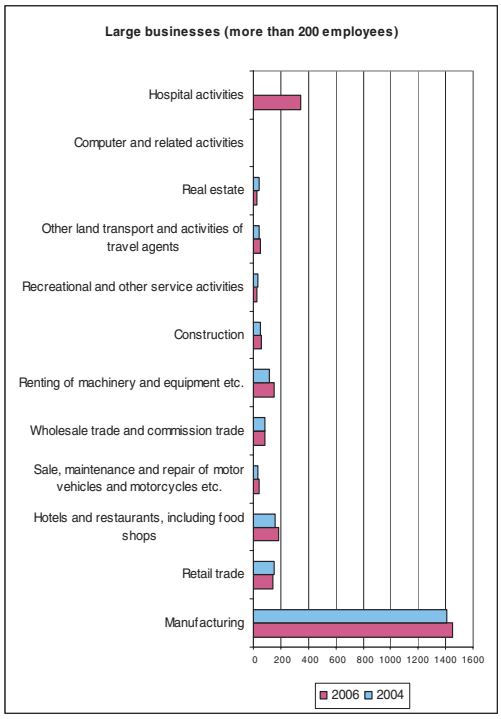
Besides employment size, there are also differences regarding employment by gender. Generally, the representation of female and male workers in services and manufacturing is balanced, with a ratio of 11 women to 10 men. As in other economies, female participation is larger in hospital activities (70 per cent) and considerably lower in sectors like construction (6 per cent).

Chart 4. Thai businesses by industry and size, 2004-2006



[8] The agricultural sector has not been taken into account in the Survey.

Chart 4. Thai businesses by industry and size, 2004-2006 (continued)



Note: No data available for hospital activities in the 2004 Survey.

Source: 2004 and 2006 ICT Business Survey in Thailand, businesses with more than 10 employees.

Based on the 2005 Survey, 9 per cent of the businesses have some level of foreign ownership, which - as shown later - is a factor linked to higher labour productivity. Foreign ownership also varies with the type of industry. Whereas hospital activities, recreational and other services firms are mainly based on domestic capital, the computer and the wholesale and commission trade sectors have a higher share of foreign capital, in 18 per cent and 12 per cent of the businesses respectively.

The following section presents detailed information on ICT use in the Thai business sector with respect to computer and Internet use, and web presence. When the data was available the results of the 2004 and 2006 ICT Business Surveys are compared.

Use of computers

Computers are an important pre-requisite for the development of the information economy. Only 1 per cent of the Thai businesses with access to Internet used computers located elsewhere than on their premises and all enterprises with web presence disposed of at least one computer. [9] The fact that mobile phone operators rely heavily on the GSM technology might explain the very low proportion of businesses accessing Internet from mobile phones (Economist Intelligence Unit, 2007). High speed Internet access through mobile technology may become available as soon as the National Telecommunications Commission starts issuing licences for more advanced third generation mobile telephony services. Results of the ICT Business Surveys indicate that only a very small number of businesses, mostly microenterprises, use Internet cafés or telecentre services. As long as alternative technology is not developed, computers will remain key for the use of Internet and for web presence in the business sector.

The 2006 ICT Business Survey shows that 81.4 per cent of the Thai businesses have at least one computer and each of those businesses has on average 14 computers available and 16 employees

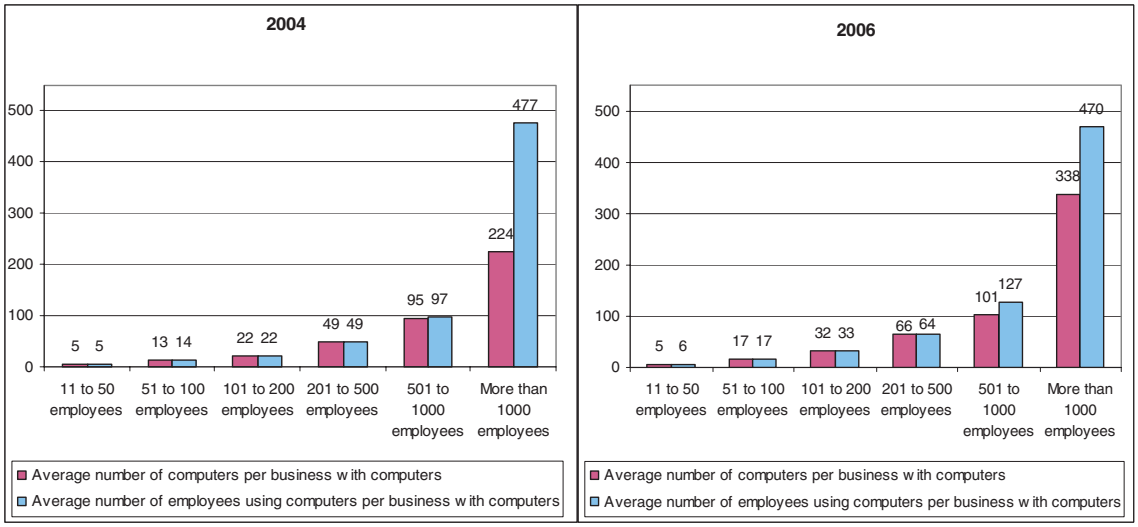
[9] Based on the 2005 ICT Business Survey.

using computers regularly. In other words, on average, there are more employees using computers than available computers. This suggests that Thai businesses have, to a certain extent, valuable human resources (i.e. computer literate staff) that would allow them to increase the use of computers. Evidence from developed countries such as Japan (2001)[10] shows that there are on average more than one computer per employee in the business sector.

Larger firms have more computers and more staff members using computers regularly in their work (chart 5). For example, a firm with 11-50 employees has on average five computers, whereas a firm with 501-1000 employees has on average 101 computers. In large firms with more than 1,000 employees the number of staff members using computers was almost double the size of the number of available computers in 2004. In 2006 the gap between the two use indicators has been reduced to some extent. More recently, businesses, in particular the large ones allocate resources more evenly between computers and the human resources who use them frequently.

Not only have large businesses more computer resources but also there is a large difference in the proportion of businesses using computers between the different size categories. All businesses with over 500 employees have at least one computer, while in smaller firms of 11 to 15 employees, this is the case for only three quarters (chart 8).

Chart 5. Average number of computers per business with computers, 2004-2006



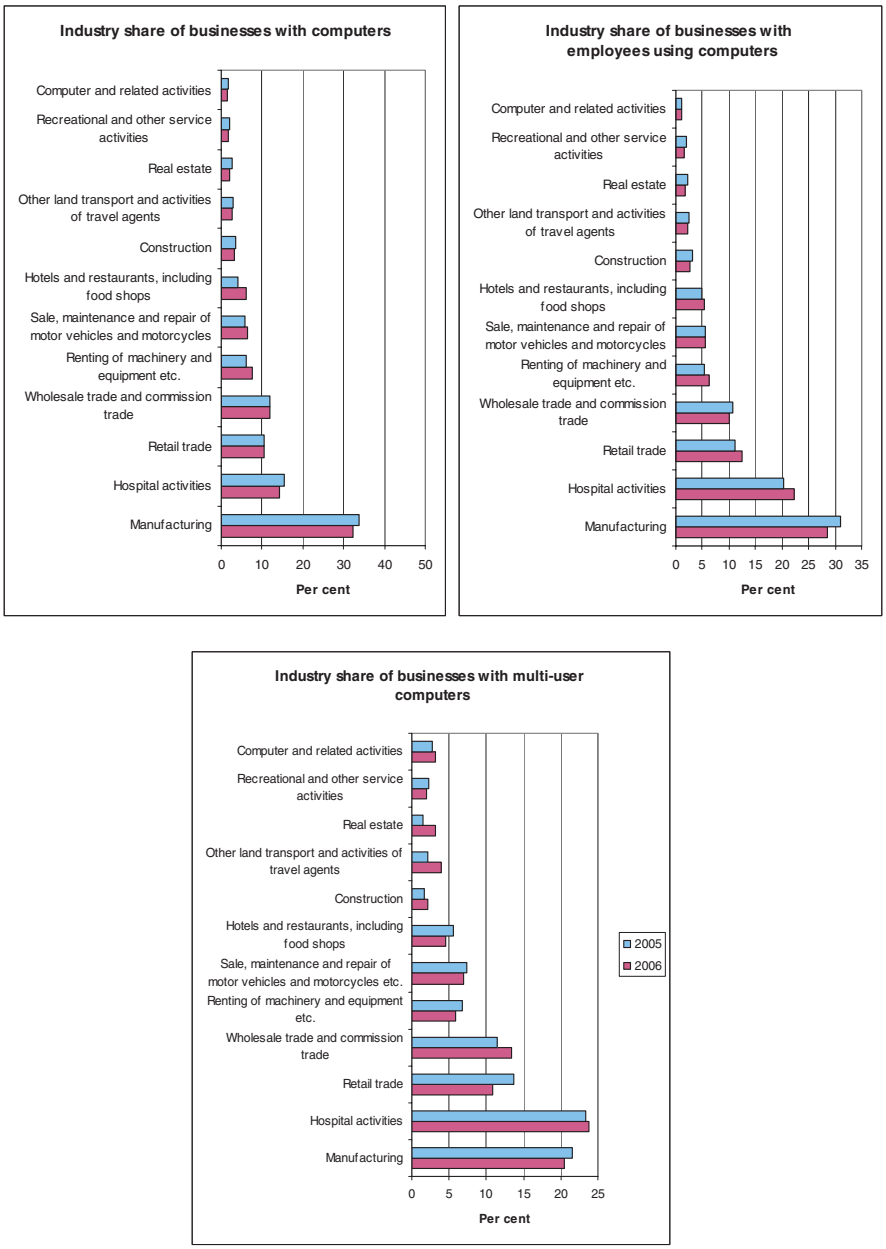
Source: 2004 and 2006 ICT Business Survey in Thailand, businesses with more than 10 employees.

The 2006 ICT Survey estimated that the business sector uses approximately 574,000 computers, almost 50 per cent up from the results of the 2004 Survey. Similarly, the number of employees using computers regularly in their work also increased by 43 per cent, now reaching 700,000. By industry, the two sectors with the biggest share of middle-sized and larger firms - manufacturing and hospitals - account for approximately half of the number of computers and computer-using employees (chart 6). From 2005 to 2006, manufacturing businesses accounted for a slightly smaller share in the total number of computers and computer-using employees, while other sectors such as hospitals, wholesale and retail trade, and hotels and restaurants increased their share.

Sharing computers among several users is easier in certain types of businesses. Computers used by more than one employee (multi-user computers) are more frequent in hospital activities and the manufacturing sector. From the 2004 to the 2006 Survey, the number of multi-user computers also increased by more than 50 per cent, to reach 48,000 units.

[10] Ministry of Economy, Trade and Industry, Survey on ICT Workplaces 2001.

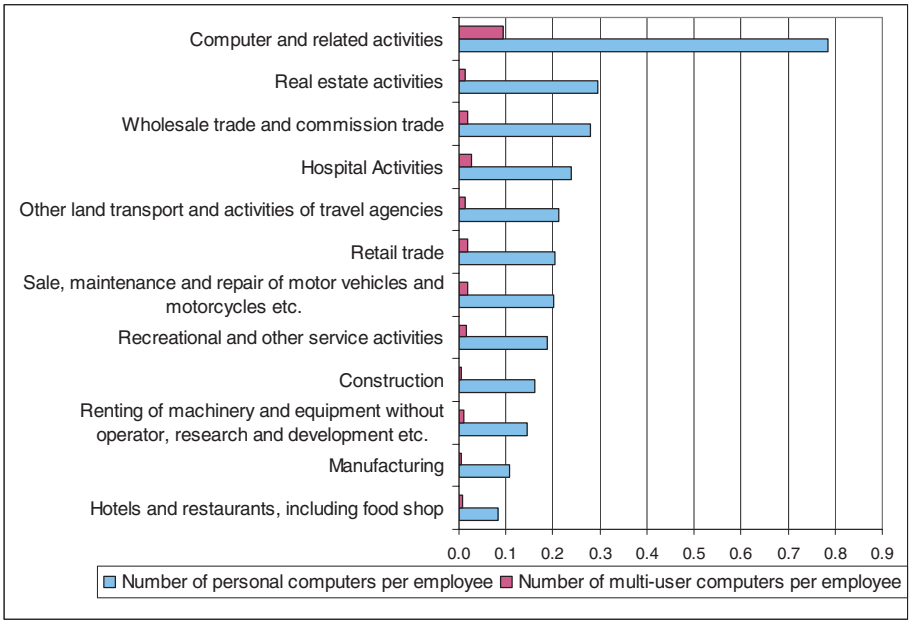
Chart 6. Share of computers, number of employees using computers and number of multi-user computers by industry, 2005-2006



Source: 2005 and 2006 ICT Business Survey in Thailand, businesses with more than 10 employees.

If looking at the relative use of computers (chart 7), the computer and related activities together with the real estate and the wholesale trade and commission trade industry have the largest share of computers per employee, indicating a higher intensity of computer use in these industries.

Chart 7. Intensity of computer use by industry, 2005



Source: 2005 ICT Business Survey in Thailand, businesses with more than 10 employees.

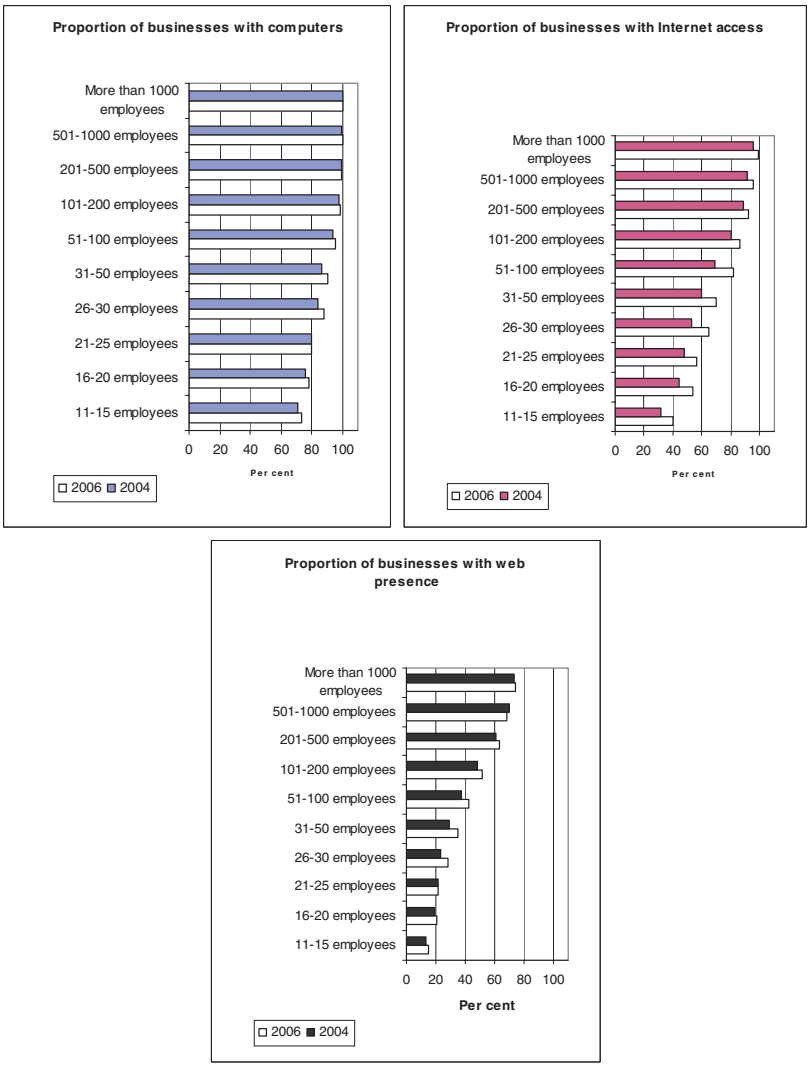
Use of Internet and web presence

Slightly more than half of the Thai manufacturing and services businesses with more than 10 employees are connected to Internet (55.9 per cent in 2006). Business size matters in terms of Internet access as it does in terms of computer and web presence use. Chart 8 shows how computer, Internet and web presence penetration increases with employment size. Whereas 48 per cent of the small businesses have access to Internet, this is true of 79 per cent and respectively 92 per cent of the medium and large businesses.

As shown before, in an overwhelming majority of cases (99 per cent), businesses access the Internet from computers located on their premises rather than in Internet cafés or telecentres. Only 385 businesses access Internet from outside their premises, despite the fact that more than 10,000 firms do not have computers and 23,530 do not have in-house Internet access. The lack of computers, in small firms in particular, goes hand in hand with the lack of Internet access for business purposes. For example all the large firms with more than 500 employees have computers and only 3 per cent of them do not have Internet access. On the other hand, among small firms with 11 to 15 employees only three quarters have computers, corresponding to 60 per cent with no Internet access (chart 8). A positive development from 2004 to 2006 has been the spectacular growth of around 10 per cent in the proportion of small and middle-sized businesses (11 to 100 employees) with access to Internet. The increase is mainly due to small firms with computers deciding to connect to the Internet.

Web presence as compared to Internet access is considerably less widespread in the business sector in Thailand. Little more than a quarter of all businesses have web presence, whether on their own websites or on sites belonging to other legal entities. Often businesses prefer to host their own website (in 89 per cent of the cases) rather than having it hosted by a different agent. Web presence is also more frequent among larger firms. The particularity is that even among the largest establishments with almost full coverage in terms of computers and Internet access more than a third remains without web presence. Whereas only a quarter of the small firms are present on the web, this is true of 42 per cent of the medium and 62 per cent of the large businesses. The proportion of businesses present on the web has grown mostly among those having 26 to 200 employees - by 5 per cent between 2004 and 2006.

Chart 8. Computers, Internet and web presence by size, 2004-2006



Source: 2004 and 2006 ICT Business Survey in Thailand, businesses with more than 10 employees.

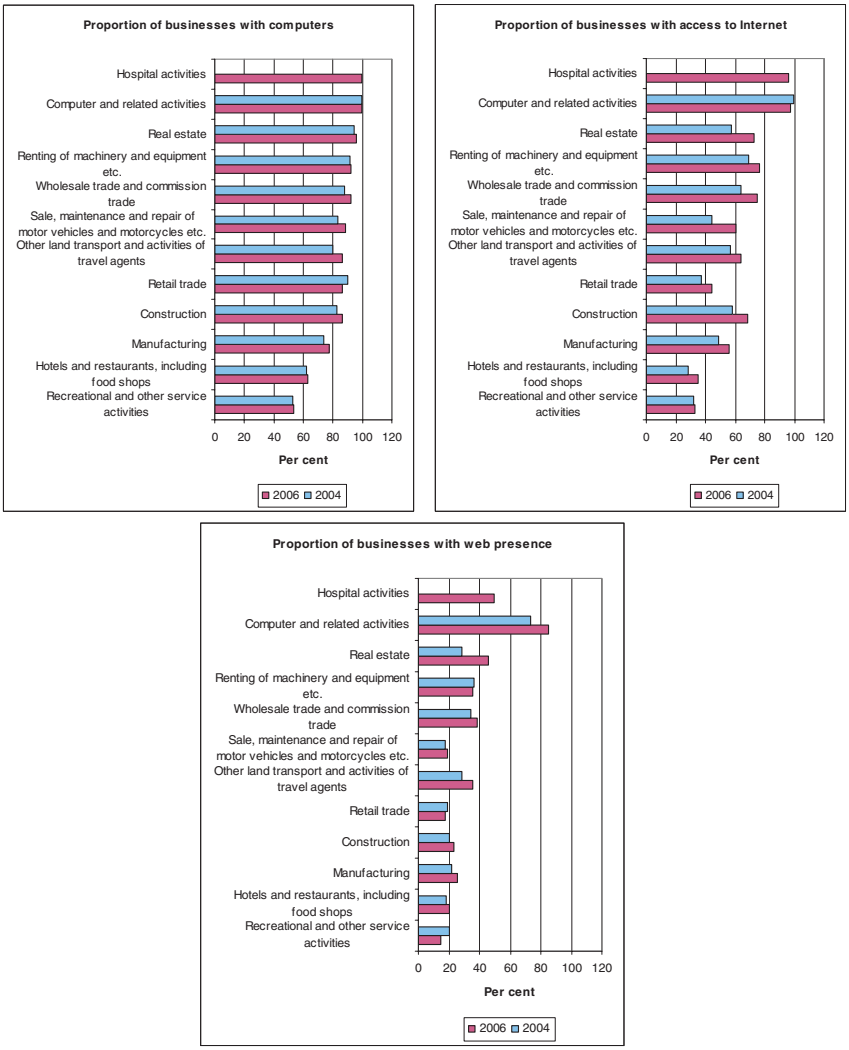
In certain economic sectors firms are more prone to using Internet and web applications due to the inherent characteristics of the business (chart 9). For example, in the computer and related services sector almost all businesses use computers and the Internet, and more than 80 per cent have web presence. This confirms findings in other studies (Maliranta and Rouvinen, 2003) whereby the ICT producing sector itself is a more frequent user of ICTs as compared to other branches of the economy. There are three other industry sectors where the use of Internet and web is more than proportional to their use of computers: renting of machinery and equipment, wholesale trade and commission trade, and other land transport and activities of travel agents. There was a sizeable increase in the proportion of businesses with Internet access from 2004 to 2006 in the real estate and the sale, maintenance and repair of motor vehicles sectors. Furthermore, the web penetration rate grew considerably in real estate and computer and related activities.

The recreational service sector ranks last in chart 9, with the lowest proportion of businesses with access to any of the three basic ICTs surveyed. However, over time, ICT usage patterns may change as businesses gain more experience and therefore it is critical to monitor such evolutions.

Although having a sizeable weight (32 per cent) in the total number of computers used in business, the manufacturing sector recorded a below average penetration of computers, Internet

and web. In 2006, only 58 per cent of the businesses in the manufacturing sector had access to the Internet and only 25 per cent had web presence, while 78 per cent had at least one computer. Since 2004 there has been a relatively positive evolution in the proportion of manufacturing businesses with computers, Internet access and web presence.

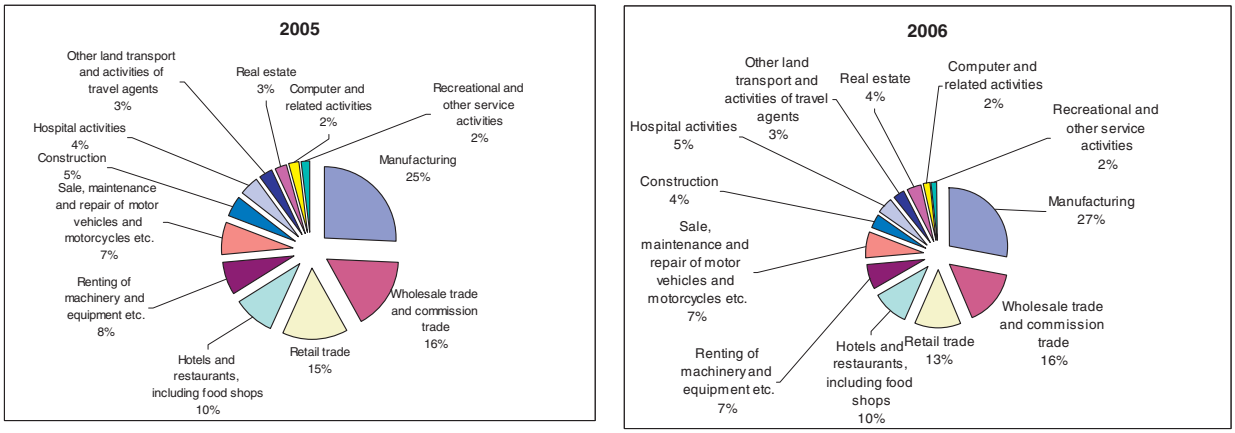
Chart 9. Computers, Internet and web presence by industry, 2004-2006



Source: 2004 and 2006 ICT Business Survey in Thailand, businesses with more than 10 employees.

Results of the 2006 Survey show that there are approximately 14,000 businesses present on the web up from 12,000 in the 2004 survey. Despite the fact that there are fewer businesses with web presence in manufacturing relative to services, the former sector still makes up for more than a quarter of the total population of Thai businesses present on the web, followed by wholesale and retail trade (chart 10). These results are in line with the composition of the Thai business sector by industry affiliation (as shown previously in chart 4).

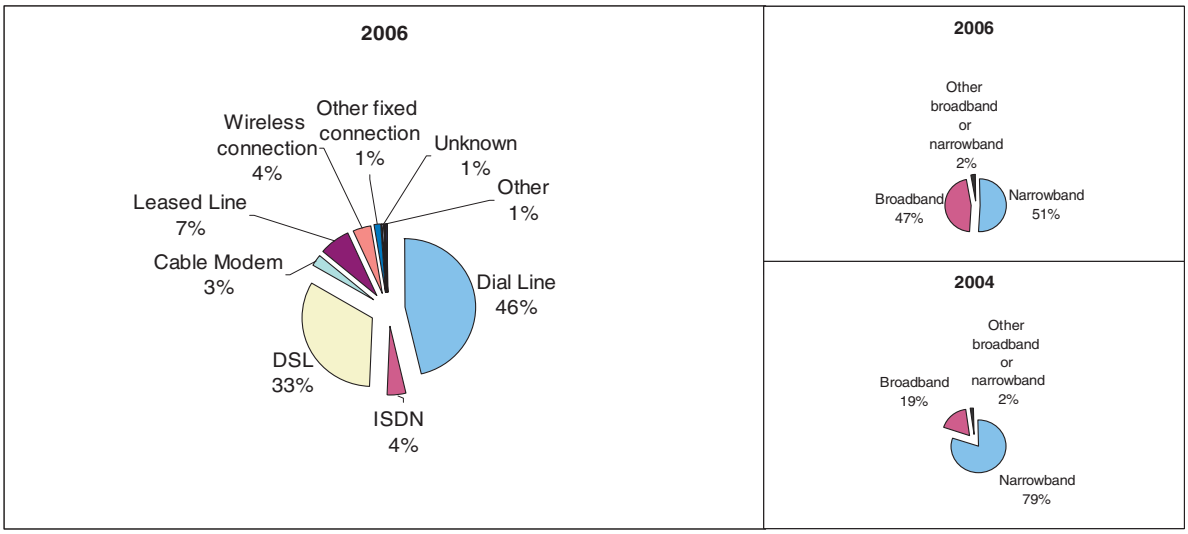
Chart 10. Businesses with web presence by industry, 2005-2006



Source: 2005 and 2006 ICT Business Survey in Thailand, businesses with more than 10 employees.

The type of Internet connection plays a crucial role in terms of the quality and speed, which could impact on competitiveness and productivity at the firm level. In Thailand, a polarisation seems to have occurred between two groups of firms: a large share of 46 per cent use slower dial-up connections and a fast growing but lower share of 33 per cent use faster DSL connections. Wireless connections remain exceptional, used in only 4 per cent of all businesses (chart 11). Internet broadband connectivity is gaining importance worldwide and has been singled out by the specialized literature as it can increase the capacity of enterprises to deliver through the Internet by providing connectivity with higher capacity and speed. In Thailand broadband access almost doubled from 2004 to 2006, to reach 47 per cent, which compares well with the 63 per cent broadband penetration in businesses from the European Union. Exceptional cases in terms of broadband penetration in Asia are the Republic of Korea, where in 2004 92 per cent of enterprises had Internet broadband access, and Singapore, where in 2005 77 per cent of enterprises with more than 10 employees had broadband access (IDA, 2005).

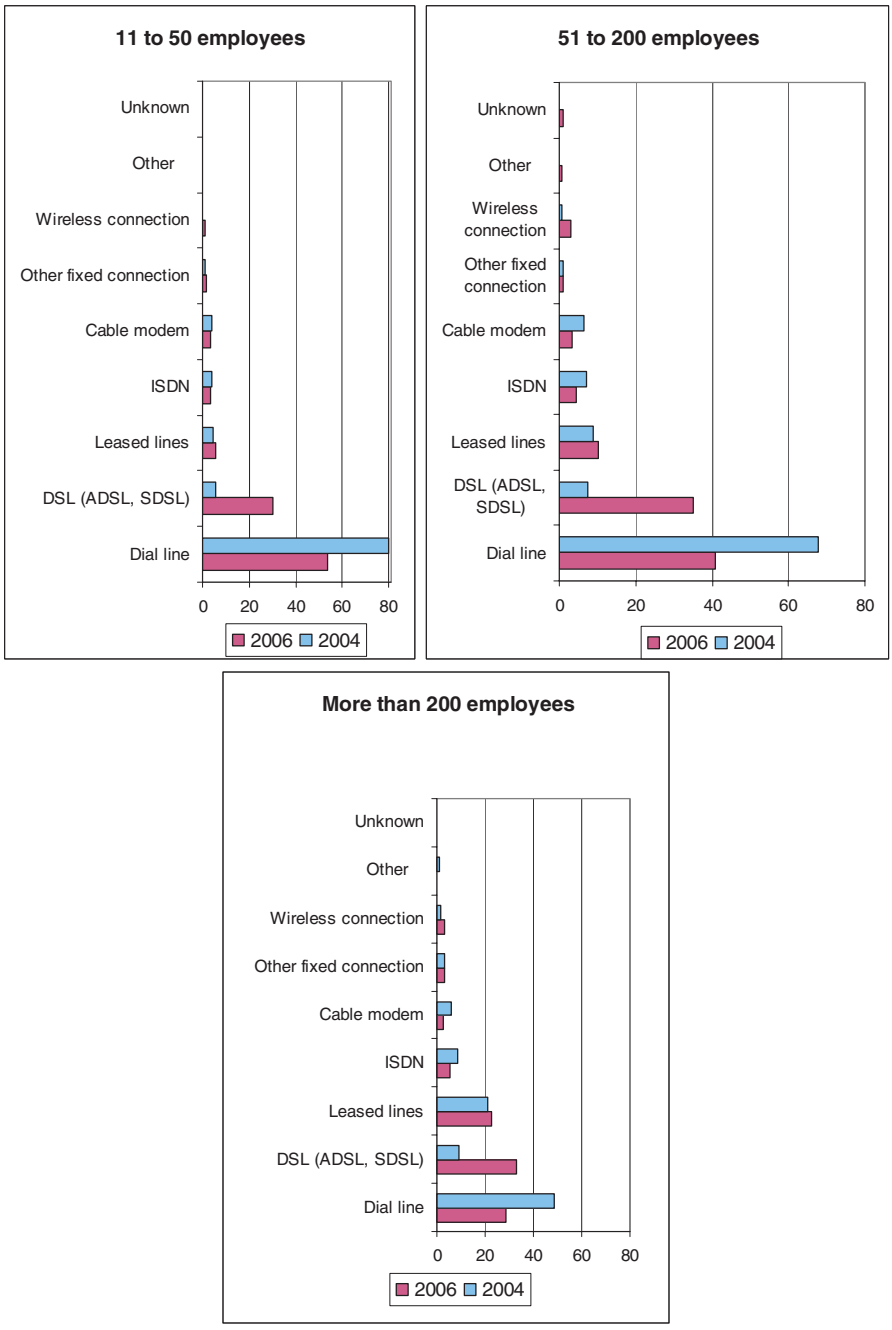
Chart 11. Type of connection to Internet in businesses, 2004-2006



Source: 2004 and 2006 ICT Business Survey in Thailand, businesses with more than 10 employees.

The type of Internet connectivity gives an additional dimension of the digital divide between the different economic groups within the country. A large majority of small and medium-sized enterprises prefer narrowband connections such as dial-up and ISDN (chart 12). In comparison, a bigger proportion of the large enterprises used broadband leased lines to connect to the Internet. From 2004 to 2006, there has been an overall shift from dial-up (narrowband) to DSL (broadband) connections. Also, in medium-sized and large enterprises the proportion of businesses using leased lines and wireless technology has increased slightly.

Chart 12. Type of connection to Internet by business size, 2004-2006



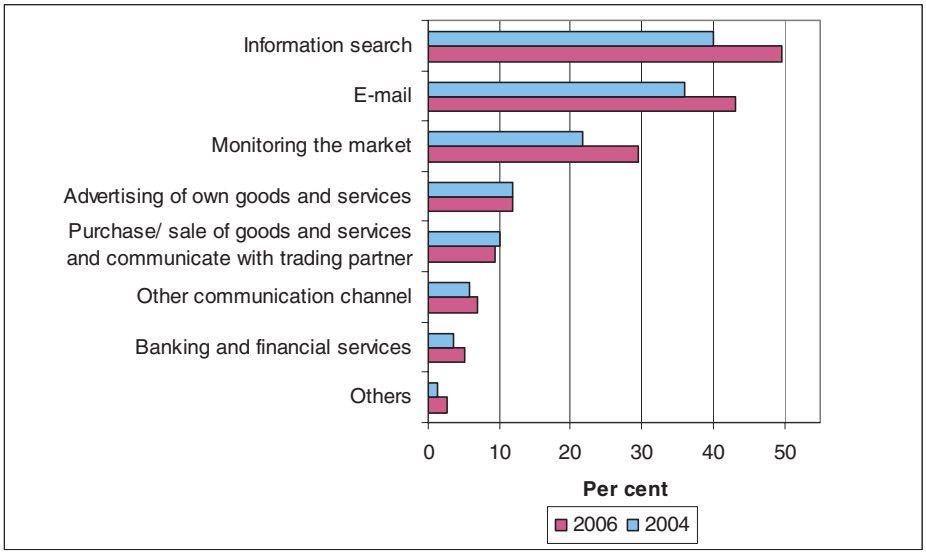
Source: 2005 ICT Business Survey in Thailand, businesses with more than 10 employees.

Since ICTs provide a wide range of advantages for doing business, such as faster and better access to information, reductions in costs and time and improved business operations to name only a few, the ICT Survey also inquired about the motivations for accessing the Internet and for

establishing web presence. In the questionnaire, enterprise representatives had the option of ticking several reasons for using the Internet or the web. For each response category, the frequency of positive answers indicates the relative importance given by businesses to a specific activity planned or carried out on the Internet or the web.

Results show that businesses access the Internet mainly for information search, which was ticked by 50 per cent of the respondents. Sending and receiving e-mail is the second most popular activity on the Internet (43 per cent), followed by monitoring the market (30 per cent). Although other online activities such as purchasing and selling products online as well as e-banking and e-finance are growing in importance in developed countries, businesses in Thailand do not consider them yet among the main reasons for using Internet. In fact, only 6 per cent of the respondents indicate that e-banking and e-finance are among the activities planned or already carried out by their firms on the Internet (chart 13). From 2004 to 2006 there has been an increase in the relative importance given by business to the three most popular activities mentioned above (information search, e-mail and monitoring the market). There is scope for improving this part of the questionnaire in order to define the response categories more precisely and avoid imprecision.

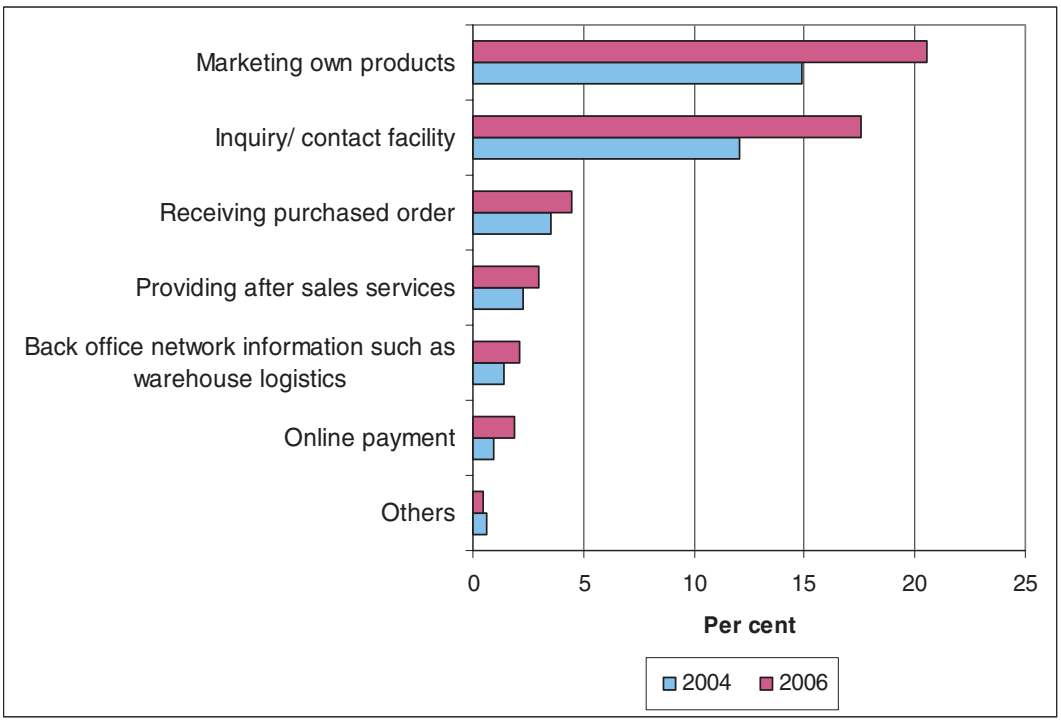
Chart 13. Reasons for using the Internet (businesses with Internet access), 2004-2006



Source: 2004 and 2006 ICT Business Survey in Thailand, businesses with more than 10 employees.

The reasons for establishing web presence are different from those for accessing the Internet. Chart 14 shows that firms present on the web indicate that they plan to use it mostly for marketing the products of the business (22 per cent) and as an inquiry and/or contact facility (17 per cent). Those activities would presumably expand the customer base as well as improve the quality of final products. Other reasons such as receiving orders online (4 per cent) or receiving online payments (3 per cent) were only pointed out by a very small share of the businesses present on the web. Over the last surveyed years, there has been a strong increase mainly in the already popular activities performed by businesses on the web, such as marketing the own business and using it as an inquiry/contact facility.

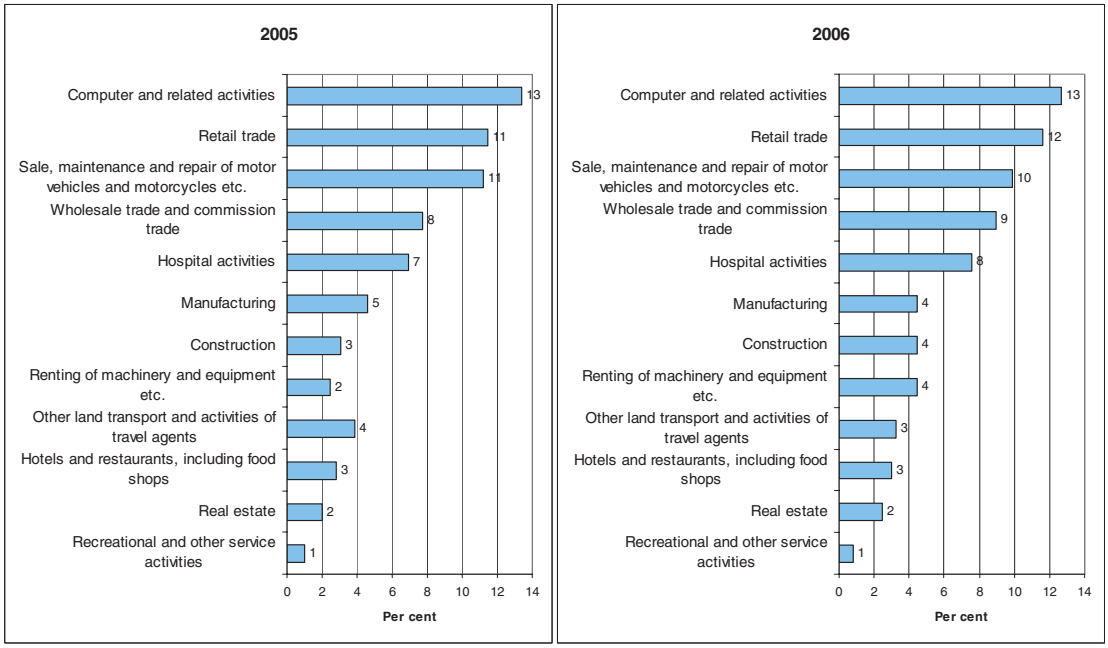
Chart 14. Reasons for web presence (businesses with web presence), 2004-2006



Source: 2004 and 2006 ICT Business Survey in Thailand, businesses with more than 10 employees.

The Surveys also tracked information on the number of firms that receive orders online (chart 15). On average, only 7 per cent of the businesses received orders online, with some variation among branches of activity between 13 per cent for the computer and related services sector and 1 per cent for the recreational and other activities industry. According to the 2006 ICT Survey the sectors with an above average proportion of businesses receiving orders online belong to the ICT-producing services industry, the retail and wholesale trade industry and hospital activities sector. Regarding the hospital industry, the growth of medical and health tourism activities may explain a relative specialization of businesses in this sector to receive orders online. The slight changes from 2005 to 2006 indicate that businesses from industries less specialized in receiving orders online have started to bridge the gap with businesses in the more specialized industries. The biggest increase is observed for the renting of machinery and equipment sector.

Chart 15. Share of businesses receiving orders online, 2005-2006



Source: 2005 and 2006 ICT Business Survey in Thailand, businesses with more than 10 employees.

Despite the relatively high share of Internet users among Thai businesses, e-commerce[11] remains confined to a small proportion of companies, as seen above in the case of e-selling. The low rate at which businesses adopt e-commerce is due to the lack of confidence in the quality of services delivered, and to concerns regarding the sophistication of web technology, the lack of secure servers and IT skills (NECTEC, 2003).

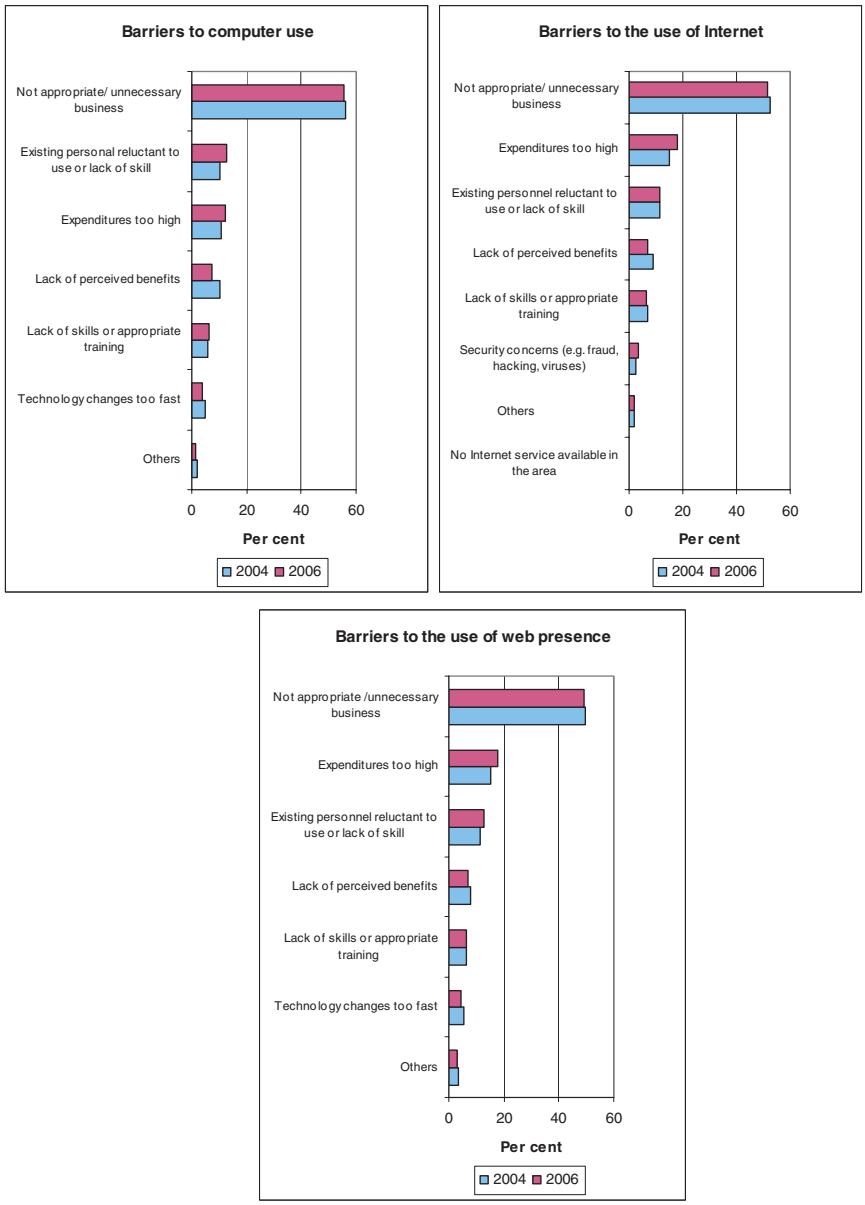
In order to understand the reasons for engaging in electronic commerce activities, the survey asked the businesses already engaged in such activities why they did it. Again, the survey provided respondents with a set of predefined response categories which they could evaluate as important, very important, not important or unknown. 94 per cent of businesses deemed the use of e-buying as important or very important for speeding up the business process and simplifying transactions. In the case of e-selling, the most important reasons for going online were speeding up the business process and expanding service beyond business hours. Other response categories considered relevant for selling online were: improving the image of the company (89 per cent), reducing business costs (87 per cent), expanding the customer base (87 per cent) and keeping up with the competition (86 per cent). Overall, results show that both buyers and suppliers engage in e-commerce because this provides them with greater efficiency.

Barriers to the use of ICT

Businesses were asked about the main barriers to the use of specific ICTs. Chart 16 presents a summary of the responses to three different questions relating to perceived barriers to using computers, accessing Internet and establishing web presence.

[11] Electronic commerce stands for commercial transactions in which the order for a good or service is made using some form of Internet-based communication. The delivery and payment may be performed off-line in the physical world.

Chart 16. Barriers to the use of computers, Internet and web presence (businesses not using ICTs), 2004-2006



Note: Multiple answers possible.
Source: 2004 and 2006 ICT Business Survey in Thailand, businesses with more than 10 employees.

Among businesses that do not currently use any of the technologies captured by the Survey (computers, the Internet or the web), as much as 58 per cent or more do not perceive the use of ICT as appropriate or necessary for their business. This problem is more often raised among firms which do not use computers. From 2004 to 2005 there was a small (1 per cent) drop in the share of businesses considering computers, Internet or the web as unnecessary for their business or as having no perceived benefits.

Two factors should be singled out as important barriers: affordability and the lack of skills and trained staff. High expenditure seems to be a barrier of greater importance in terms of accessing the Internet or establishing web presence as compared to using computers. More ICT-related skills and training are needed in firms without Internet connection and web presence (compared

to using computers). Since the lack of skills has been identified as one of the factors hindering further ICT development, Thailand has included training and education in information technology as a main pillar in its national ICT plan.

Results of the survey also show that Internet security and service failures are not the most important perceived entry barriers for using the Internet. An additional issue of interest may be to investigate if security concerns represent a major difficulty for firms already connected to the Internet.

This section of the report has described the main patterns of computer, Internet and website use by the businesses sector in Thailand. What follows is a closer look at the specific characteristics of ICT use in *manufacturing* firms, which is the focus group of the impact analysis carried out under this project. The next section is based on a comparison of data from the 2003 Manufacturing Survey (reference year 2002) and the 2005 ICT Survey (reference year 1 April 2004 - 30 March 2005).

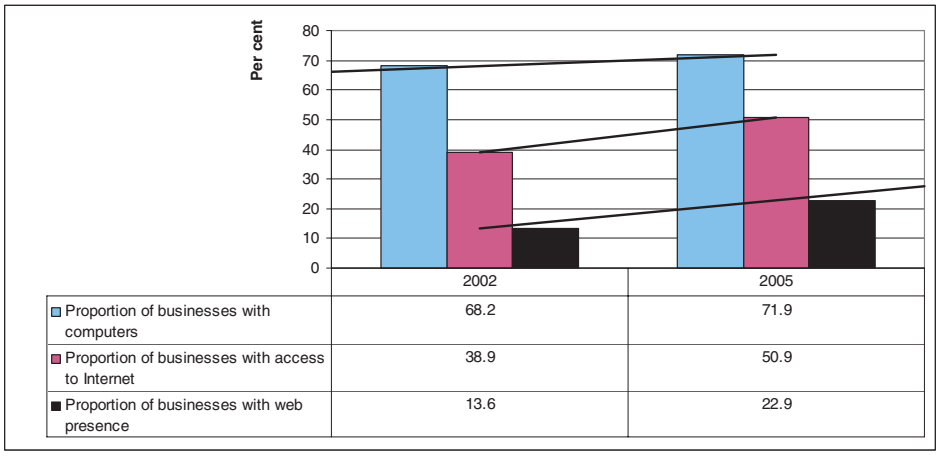
4. ICT use in manufacturing firms

Manufacturing firms account for a substantial share of the business sector in Thailand (almost a third), they tend to have a larger than average number of employees per establishment and have moderate users of ICTs. There is a larger concentration of manufacturers in Bangkok, its vicinity and the Central region of the country, while services are considerably less concentrated.

In terms of ICT uptake, the manufacturing sector has a below average penetration of computer, Internet and web presence compared to services. However, due to the considerable size of the sector, manufacturing businesses still account for almost a third of the number of computers and that of computer-using employees in the country.

From 2002 to 2005, there has been a positive evolution in all the available indicators of ICT use in manufacturing. As shown in chart 17, the share of manufacturing businesses using computers has increased by 4 per cent, from 68.2 per cent to 71.9 per cent. Internet penetration has grown most (by 12 per cent), followed by the share of firms with web presence (9 per cent). These figures show a faster evolution of ICT use in 2002-2005 in manufacturing than the current trend experienced by the entire business sector in 2004-2006 (see chart 17).

Chart 17. Computers, Internet and web presence in the manufacturing sector, 2002-2005



	2002	2005
Proportion of businesses with computers	68.2	71.9
Proportion of businesses with access to Internet	38.9	50.9
Proportion of businesses with web presence	13.6	22.9

Source: 2003 Manufacturing Survey and 2005 ICT Business Survey in Thailand, businesses with more than 10 employees.

Use of computers

Computer penetration has reached a high level among manufacturing businesses, with 72 per cent using at least one computer in 2005.

A firm with 100 employees has on average 12 employees using computers and 11 computers (table 2). The intensity of computer use has improved during the two years considered, with the number of computer-using employees remaining slightly superior to that of available computers per business unit. However, in manufacturing as well as in the rest of the business sector the number of computers grew faster than the number of employees using computers. Thus figures show that since 2002 businesses invested more in computers and that the new investment has resulted in a reduced ratio of employees per computer. More investment in computers has brought a change in the type of tasks performed with computers, but it is also likely to determine a growing demand for more computer literate employees.

Table 2. Intensity of computer use in the manufacturing sector, 2002-2005

	2002	2005	Growth rate (%)
Average number of employees using computers per 100 employees	9.0	12.2	35.6
Average number of computers per 100 employees	7.8	10.7	37.2
Average number of employees using computers per 100 employees in businesses with computers	14.7	17.6	19.5
Average number of computers per 100 employees in businesses with computers	11.5	15.3	33.3

Source: 2003 Manufacturing Survey and 2005 ICT Business Survey in Thailand, businesses with more than 10 employees.

Use of Internet and web presence

In 2005 just over half (51 per cent) of the manufacturing businesses had access to the Internet, compared to 71 per cent of the firms with computers.

Almost a quarter (23 per cent) of the manufacturing firms had web presence in 2004. This figure corresponded to a 45 per cent proportion of the businesses with computers connected to Internet and suggests that, unlike Internet, web presence is in an earlier stage of adoption. None of the manufacturing businesses was found to have web presence in absence of Internet access and computers on its premises.

The only question on the type of activity carried out over the Internet included in the 2003 Manufacturing Survey relates to e-commerce activities - placing and receiving orders online. Accordingly, in 2002, 7 per cent of the manufacturers (located in urban areas, with more than 10 employees) sold goods and services online. The proportion of manufacturers which placed orders online (i.e. buying over the Internet) was much higher - close to 20 per cent[12] in 2002.

ICT use and economic performance

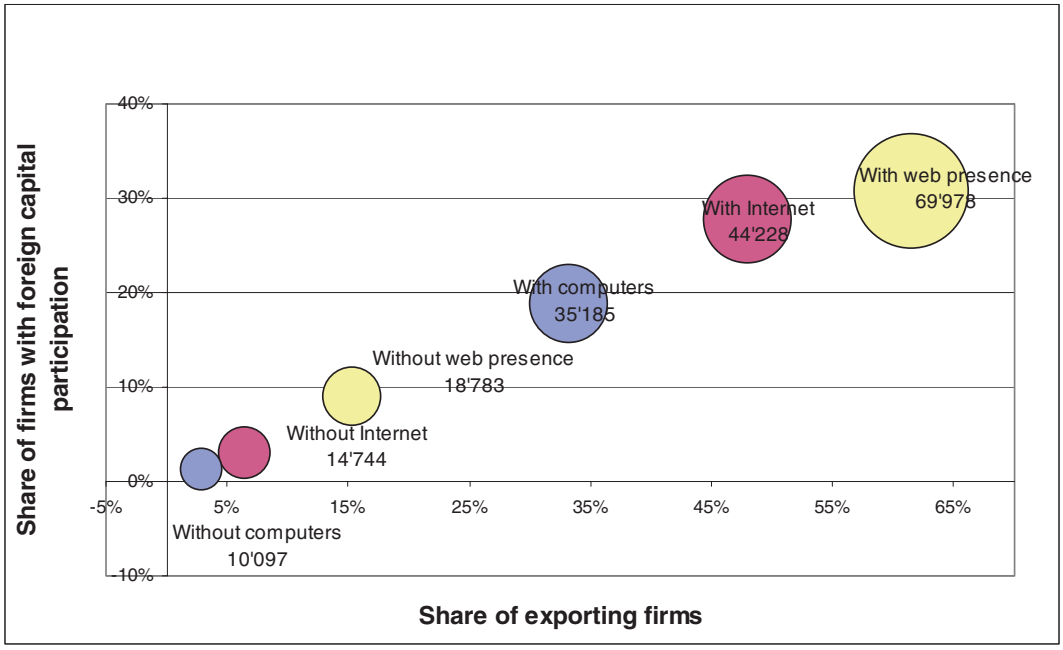
Economic performance is stronger in firms that use ICT and even more so in firms that use a combination of several ICTs. Manufacturers using computers have on average 10 times higher sales per employee than manufacturers without computers (chart 18). The order of magnitude is higher when comparing sales per employee in firms with and without web presence.

In 2002, exporting firms generated three quarters of total sales in the Thai manufacturing sector, while firms with foreign capital participation accounted for 62 per cent of total industry revenues. There were very few Thai manufacturing firms without computers that exported or attracted

[12] This figure is based on the positive answer to the sub-question regarding activities on Internet (identified as shopping activity among Internet users in the 2003 manufacturing survey).

foreign capital investment. On average, of 100 exporting Thai manufacturers, 91 had at least one computer, 77 were connected to the Internet and only 35 had a web presence.

Chart 18. Average sales per employee in the manufacturing sector ($ per employee), 2003



Source: Thai Manufacturing Survey 2003, businesses with more than 10 employees.

Chart 18 illustrates average sales per employee in firms with computers, Internet and web presence in terms of their export position and foreign capital participation. A typical manufacturer with at least one computer receives revenues of $ 35'185 per employee yearly. A total of 33 per cent of businesses with computers are exporters and 19 per cent benefit from foreign capital participation. This confirms that computers are distributed throughout Thai manufacturing businesses and are not used exclusively by foreign-owned firms or by exporting firms.

Among firms with Internet access and web presence, exporting and foreign-owned firms had a higher participation. A typical manufacturer with at least one computer connected to the Internet earns on average more than firms with computers - ($ 44,288 per employee); but 48 per cent of Internet-connected businesses are exporters and 28 per cent receive foreign capital. The shares of exporting and foreign-owned firms are even higher among web-present manufacturers (61 per cent and 31 per cent). This suggests that web presence is used more frequently by exporting firms, possibly for the purpose of following foreign market developments (information search).

Manufacturers with foreign capital participation do not establish web presence as frequently as exporting firms. Foreign capital participation seems to make more difference in terms of Internet access and less in terms of web presence, possibly owing to the existence of different management practices and requirements in foreign firms. The high share of exporters among manufacturers present on the web could be related to the language used or the relative scarcity of Internet content in the Thai language.[13] However, available data provided no information on the language used by firms on websites or about the characteristics of their target customers.

[13] The Economist Intelligence Unit (2007) also shows that there are relatively few websites with content in the Thai language.

So far, the Report has presented an overview of ICT use in the Thai business sector, and in particular in Thai manufacturing. The next section will turn to the question of how ICT use may impact on firm productivity.

5. Measuring ICT impact on labour productivity

ICT use and firm labour productivity

At the firm level, analysis assessing the impact of ICT use on productivity can yield a complex set of results. Variables on ICT use have different productivity effects in conjunction with other control measures such as firm age, the share of foreign capital participation or access to more skilled human resources. For example, the estimated impact of a larger proportion of employees using computers was found by some studies to be more pronounced in young manufacturing firms (Maliranta and Rouvinen, 2003). Similarly, other studies focus on the specific impact of ICT in small and medium sized enterprises, as compared to larger businesses. To make it easier to keep track of the different empirical applications of firm level productivity models, this section groups the many dimensions into three main categories, by components of the analysis (table 3): variables measuring labour productivity, ICT variables and complementary factors likely to influence the ICT-productivity relationship.

Table 3. Key variables for measuring the impact of ICT on labour productivity

Labour productivity variables	ICT variables	Complementary/control variables
• Sales per employee • Gross output per employee • Value added per employee • Or recalculations of the above variables based on effective hours worked by employees	*Binary (dummy) variables*: take on value 1 if firm has access to a specific technology and 0 otherwise. *Numerical variables*: • Spending on specific ICTs • ICT capital stock • Share of employees using ICTs • Number of computers available in the firm	• Firm age • Ownership • Affiliation to a multi-unit firm • Skill mix (share of employees working directly in production) • Level of education • Industry sector of activity (corresponding to ISIC codes) • Geographical region • Factors of Cobb-Douglas production functions (ordinary capital stock, employment, cost of materials)

Labour productivity is commonly measured either as value added per employee or as sales per employee. Criscuolo and Waldron (2003) derive results for both measures of productivity and find that the impact of e-commerce[14] was slightly stronger on value added than on sales. Conversely, Atrostic and Nguyen (2002) rely on the findings of Baily (1986) to argue that using value added as a measure of labour productivity yields systematically biased estimates of the theoretically correct growth model. Outside the context of empirical models, value added is a more precise measure of labour productivity since it subtracts from the value of sales the costs incurred with intermediate consumption. For those considerations, analysing the impact of ICT on sales per employee was considered more appropriate for this study.

The empirical models presented here draw on several types of variables for describing the use of ICT. Binary variables, which distinguish between firms with and without access to, for example, Internet, are easy to collect and provide input for analyses of differences between the haves and the have nots. Empirical studies also test for the effect of intensity in ICT uptake – for example, the share of capital devoted to computer investments – and intensity of ICT use, such as the number of computers available or the share of employees using e-mail. From a theoretical point of view, findings based on numerical rather than binary variables are more powerful. Maliranta

[14] Measured as placing or receiving orders on line.

and Rouvinen (2006) proposed a slightly different modelling structure in which they estimate the net effects of several complementary features of computers: processing and storage capacity, portability and wireless and wireline connectivity. In their model, the positive labour productivity effect associated to the portability of computers is complementary to that of the basic processing and storage capacity of any computers whether portable or not.

The different variables of intensity in ICT use by enterprises analysed by the specialized literature are not the ideal measures. As some have emphasized,[15] ICT use becomes increasingly relevant to productivity when combined with soft skills such as good management and superior marketing abilities. Unfortunately, such soft skills and soft technology inputs cannot be quantified directly and therefore their effect is hard to assess. Empirical research usually corrects for this unknown effect by accounting for different economic results in foreign-owned firms, in exporting companies, in establishments belonging to multi-unit corporations or simply in more experienced firms. Therefore, policy implications derived from such research do not directly recommend that the intensity of ICT use be scaled up (for example by increasing the number of computers per employee). Rather they recommend investigating how the combined use of ICT and superior managerial capabilities can account for variations in ICT gains between firms with different characteristics.

ICTs can generate higher market shares either by reducing input costs and thus allowing firms to produce more of the same products, or by improving the quality of products or product packages, with, as a result, additional sales or higher-priced products. Empirical results presented here cannot distinguish between those two effects. More information on the evolution of prices in different sectors is needed in order to assess which effect prevailed in defined periods of time.

In accordance with the framework presented in table 3, the following section shows the most common complementary factors to the ICT-productivity relationship highlighted by the specialized literature.

Complementary factors explaining the ICT–productivity relationship

Control variables are additional elements likely to contribute to explaining productivity variation between firms. They also give a different dimension to results relating to ICT use and productivity when used in conjunction (interacted) with measures of ICT.

In several studies, firm age has proved to be an important element explaining productivity effects. The European Commission's Enterprise and Industry Directorate General showed in a report (Koellinger, 2006) that the dynamic evolution of new firms is a source of economic growth and employment and that new firms also contribute significantly to the diffusion of e-business applications in Europe. In terms of econometric results, Maliranta and Rouvinen (2003) estimate that young manufacturing firms in Finland, unlike older ones, have 3 per cent higher productivity gains from the use of computers. Also, young Finnish services firms appeared to be 1 per cent more productive thanks to access to the Internet.

In a different study, Farooqui (2005) runs four different growth models on young and older British firms in manufacturing and services taken separately. Results show that ICT indicators such as investment in IT hardware and software and the share of ICT-equipped employment have a more pronounced impact on young manufacturing firms as compared with older ones.

The same finding did not apply to young British services companies, however, on that issue, Atrostic and Nguyen (2005) draw attention to the fact that the measure of capital input used in most papers – the book value of capital – is a more accurate proxy in the case of the new firms. Older firms' capital input is not properly captured by book values because this measure is evaluated at initial prices when capital assets were acquired as opposed to current asset prices. The first best proxy to use would be the current value of the capital stock computed by means of

[15] For example, Brynjolfsson and Hitt (2002).

the perpetual inventory method by using information on yearly capital investments, depreciation and current asset prices. But in many cases, data are not available on all the above-mentioned variables. Regression results using the book value of capital assets are likely to give biased results for older firms and more accurate results for younger ones.

Firms with foreign capital participation seemed to have higher labour productivity. With regard to developed countries, Bloom, Sadun and van Reenen (2005) estimated that in their large sample of UK firms from all business sectors, US-owned establishments had significantly higher productivity gains from IT capital than other foreign-owned firms or domestically owned firms. This result can be linked with macro-level findings which indicated that the United States had acquired greater labour productivity from investment in ICT than all other developed countries, especially since the mid-1990s. More productive US-owned firms appear to be better managed or have access to more efficient ICT solutions.

Similarly, firms belonging to multi-unit networks of affiliates may have greater labour productivity since they dispose of additional resources to draw from in the subsidiary–headquarters management structure. A multi-unit corporate configuration may justify benefits from network effects (a success story replicated in several subsidiary branches) and access to superior management resources.

The skill mix of production and non-production workers and the level of education in the regions where companies are located were considered by some studies to be complementary to the measures of ICT use by firms. Better-skilled workers are more likely to be able to develop, use and maintain more advanced technology. Maliranta and Rouvinen (2003) comment that growth models need to control for the human capital characteristics of employment and labour because these variables are essentially complementary to ICT uptake and omitting them would inflate the labour productivity gains from ICT.

Last but not least, when quantifying the relationship between ICTs and labour productivity one needs to control for differences in demand and supply factors. For example, in many countries businesses located in the vicinity of the capital benefit from higher demand than those located in isolated provinces simply because there is a high concentration of the population in capitals. In a similar way, different industries have distinct labour productivity averages owing to both demand and supply factors. For example, an oil-producing company is very likely to have higher sales per employee than a light industry manufacturer specialized in food and beverages of the same size (because of industry characteristics such as price, labour intensity and type of consumer good). It is therefore necessary to take into account regional and industry-specific characteristics when accounting for the contribution of ICT to labour productivity growth.

The ICT-producing sector itself benefited from ICT use that considerably exceeded domestic industry averages. Maliranta and Rouvinen (2003) estimate that in Finland firms belonging to the ICT-producing sector had 3 to 4.5 per cent higher labour productivity gains from ICT use than the rest of the manufacturing and services companies in the sample. This may be because ICT producers have a know-how advantage over other ordinary users in terms of how to best put to work specific technology to enhance labour productivity.

Impact of specific ICTs on productivity

Use of computer networks (such as the Internet, intranet, LAN, EDI and Extranet) had an estimated 5 per cent positive effect on labour productivity in a large sample of American manufacturing businesses (Atrostic and Nguyen, 2002). The model considered a theoretical framework in which use of computer networks made a "disembodied" contribution to technological change other than that of capital and labour. Atrostic and Nguyen (2005) take up again the impact of computer networks in a slightly modified empirical model. The novelty of their approach consists in using two different computer-related measures in the labour productivity regression: computer capital, as distinct from ordinary capital, and the computer network binary variable used previously. In their view, having separate measures for the presence

of computers (computer investment) and for how computers are used (computer networks) is crucial for estimating accurately the two effects on labour productivity. When using a sample composed only of newly registered US manufacturing firms, they find that the contribution of computer networks added 5 per cent to labour productivity while investment in computers added 12 per cent. Within the entire data set of older and younger US manufacturing firms, the contribution of computer capital dropped to 5 per cent and there was no evidence of a positive effect on computer networks any more. However, as mentioned before, most empirical studies tend to find that ICT use has less impact on older manufacturing firms, and this may be due to a measurement bias as explained in Atrostic and Nguyen (2005).

E-commerce also has a significant impact on labour productivity in firms, with a marked difference between businesses that buy and those that sell online. Criscuolo and Waldron (2003) analyse a panel of UK manufacturing firms and find that the positive effect of placing orders online ranged between 7 and 9 per cent. On the other hand, they estimate that firm labour productivity was 5 per cent lower for those that used e-commerce for receiving orders online (online sellers). Lower labour productivity associated with selling products online is likely to be due to price effects. The prices of products sold online are considerably lower than the prices of similar goods sold through different channels. Additionally, firms which specialize in selling online may have difficulties in finding suppliers from which to buy online as much as they would want. Larger firms with a stronger position in the market may be able to better cope with balancing the extent of e-buying and e-selling. In a larger and updated UK data set of manufacturing and services firms, Farooqui (2005) finds again that e-selling negatively impacts on labour productivity in manufacturing, while e-buying has a larger and positive effect. In particular, Farooqui (2005) finds that in distribution services e-buying boosts labour productivity by 4 per cent.

Several studies show that measures of ICT use by employees are also reflected in enhanced firm productivity. Within a large panel of Finnish firms Maliranta and Rouvinen (2003) compare the impact of computer use on labour productivity in manufacturing and services sectors. A 10 per cent increase in the share of computer-equipped labour raises productivity by 1.8 per cent in manufacturing and 2.8 per cent in services. On the other hand, a higher share of employees with Internet access was found to have a significant impact only on services firms (2.9 per cent). The study considers Internet use as a proxy for external electronic communication and LAN use as a measure of internal electronic communication. Findings show that manufacturing firms benefit more from better internal communication, while services firms gain more from improved external electronic communication. A 10 per cent higher share of employees using LAN in the manufacturing sector results in 2.1 per cent higher labour productivity.

A similar study on a mixed sample of Swedish manufacturing and services firms estimated that a 10 per cent higher share of computer-equipped labour boosts productivity by 1.3 per cent (Hagén and Zeed, 2005). The Swedish study also estimates productivity effects deriving from access to broadband of 3.6 per cent. With the help of a composite ICT indicator, Hagén and Zeed (2005) show that adopting an ever-increasing number of ICT solutions has positive but decreasing effects on labour productivity in Swedish firms. Each additional level of ICT complexity seems to add less to firm productivity.

Farooqui (2005) also identifies the use of computers and the Internet by employees as a proxy of work organization and skills. In the United Kingdom, a 10 per cent increase in the share of employees using computers raised productivity by 2.1 per cent in manufacturing and 1.5 per cent in services. These effects are additional to the impact of ICT investment, also accounted for in the Farooqui (2005) model. Similar estimates for Internet use by British firm employees showed 2.9 per cent for manufacturing and no significant impact for services.

Maliranta and Rouvinen (2006) estimate the impact of different complementary computer features on labour productivity in a 2001 sample of Finnish services and manufacturing firms. Their computer variables are measured in terms of share of employees using computers with one or several of the following features: processing and storage capabilities, portability and wireline or

wireless connectivity. They find that a 10 per cent higher share of labour with access to basic computer attributes such as providing processing and storage capabilities increases labour productivity by 0.9 per cent. In addition, computer portability boosts output per employee by 3.2 per cent, wireline connection to the Internet adds 1.4 per cent, while wireless connectivity adds only 0.6 per cent.

There is an emerging literature estimating the impact of broadband on firm productivity. Gillett et al. (2006) were the first to quantify the economic impact of broadband and found that there were positive and significant effects on the number of workers and the number of businesses in IT-intensive sectors.

ICT investment, soft technologies and total factor productivity gains

A different empirical question was addressed by Brynjolfsson and Hitt (2002). They explore the impact of computerization on total factor productivity and output growth in a panel data set of 527 large US firms over a period of eight years (1987-1994). They compare the short-run and long-run effects of computerization on total factor productivity growth by taking first and five- to seven-year differences of the log-linear output function. The aim of their analysis is to understand the mechanism through which private returns from computerization accrue, since they are the ultimate long-run determinants of decisions to invest in ICTs.

They model production as a function of computer capital and other inputs, and assume that in the presence of computers, the efficiency of employees, internal firm organization and supply-chain management systems are improved. They find that, in the short run, investments in computers generated an increase in labour productivity primarily through capital deepening, and found little evidence of an impact on total factor productivity growth. However, when the analysis is based on longer time differences, results show that computers have a positive effect on total factor productivity growth. In the long run, the contribution of computer capital to growth rises substantially above computer capital costs, and this is then reflected in terms of total factor productivity. Their interpretation is that computers create new opportunities for firms to combine input factors through business reorganization. Brynjolfsson and Yang (1999) had previously estimated that computer adoption triggers complementary investments in "organizational capital" up to 10 times as large as direct investments in computers.

To conclude, there is a large variety of results derived for the impact of specific ICTs on firms from different countries and industries. See annex 1 for a summary of the results captured by the literature review. A combination of soft technologies and smart ICT use can lead to multifactor productivity gains but this process takes time and requires complementary spending on other resources additional to ICT investment. Most measures of ICT use had a positive effect on productivity across the board - with the exception of exclusively selling online. However, the top most fortunate firms in terms of gains from Internet use, for example, could have slightly different characteristics from country to country. They may belong to different industries or they may have been in the market for a longer time. Therefore such results cannot always be generalized. Accordingly, it is useful for developing countries to conduct similar empirical studies to reveal the particularities of the way in which local firms gain from ICTs.

More research, based on developing country data, is needed in order to ascertain how and when ICT use increased production efficiency in firms and which ICT was used. A comparison of estimation results across different countries, industry sectors and technologies can provide policymakers with additional information for fine-tuning ICT policy master plans. As an illustration, the next section presents the results of a firm-level productivity model applied to the manufacturing sector in Thailand.

6. Presentation of the model

The primary goal of the analysis was to quantify the relationship between ICT use and labour productivity in Thai manufacturing firms. In the analysis, which built on methods employed in similar studies, firm productivity was modelled on the assumptions of a Cobb–Douglas production function with three input factors: capital, labour and spending on materials (see box 1).

Box. 1. The empirical model

The regression equation is based on a linearized version of the Cobb–Douglas function[16] (equation 1). Labour productivity is regressed on factor inputs (capital, labour, spending on materials), one or several ICT variables and a set of controls for industry and regional attributes of demand and supply, the presence of foreign capital participation and the activity of multi-unit firms (head offices or branches).

$$\ln\left(\frac{sales_j}{L_j}\right) = \beta_0 + \beta_1 ICTVariabl\,e_j + \beta_2 \ln\left(\frac{K_j}{L_j}\right) + \beta_3 \ln\left(\frac{M_j}{L_j}\right) + \beta_4 \ln(L_j) + \beta_5 Multi\_unit_j +$$
$$+ \beta_6 Foreign\_capital_j + \sum_r \beta_r region\_r_j + \sum_i \beta_i Industry\_i_j + u_j$$

,where K is capital, L is employment and M is spending on materials. (equation 1)

With the data available from the Manufacturing Survey 2003 it was possible to run two similar models based on the same Cobb–Douglas framework: one using total employment as a common denominator and the other using total effective employment. Effective employment is total employment adjusted to reflect the declared number of hours effectively worked during 2003. Results derived from the two models could be used as a check for the robustness of estimates. From a theoretical point of view, the effective labour productivity model is more accurate since it accounts for variations in the hours effectively worked by employees rather than assuming that all employees worked an equal number of hours. Empirically, the accuracy of results depends on the quality of data. The model employed for effective labour productivity is described by equation 2.

$$\ln\left(\frac{sales_j}{L\_effective_j}\right) = \beta_0 + \beta_1 ICTVariable_j + \beta_2 \ln\left(\frac{K_j}{L\_effective_j}\right) + \beta_3 \ln\left(\frac{M_j}{L\_effective_j}\right) + \beta_4 \ln(L\_effective_j$$
$$+ \beta_5 Multi\_unit_j + \beta_6 Foreign\_capital_j + \sum_r \beta_r region\_r_j + \sum_i \beta_i Industry\_i_j + u_j$$

,where K is capital, L_effective is effective employment and M is spending on materials. (equation 2)

White (1980) heteroskedasticity consistent standard deviations were calculated.

When the ICT variable employed is a dummy variable, the β1 estimate is transformed into an elasticity coefficient equal to $e^{\beta_1} - 1$ (Halvorsen and Palmquist, 1980). When the ICT variable is expressed as a share in total employment, the β1 estimate is interpreted as a semi-elasticity coefficient in the sense that a unitary increase in the ICT variable is associated with β1 percentage change in the amount of sales per employee.[17]

The analysis also identified differences based on geographical location, industry sector, firm size and age and their influence on the ICT use–productivity relationship. This was done by estimating interactions of ICT measures with control variables within the same Cobb–Douglas theoretical framework.

By looking at the performance of firms with and without specific ICTs the analysis could quantify the extent to which during 2002 Thai manufacturers[18] with similar characteristics had higher productivity when using ICTs. Further research with comparable data on several years could investigate the impact of past levels of ICT use on current labour productivity. The analysis could not establish whether beyond correlation, there is a causal relationship between ICT use

[16] See for example Atrostic and Nguyen (2002) for the theoretical derivation of the empirical model.
[17] See for example Maliranta and Rouvinen (2003) for the theoretical derivation of the model using the share of employees using computers.
[18] The source of the data is the 2003 Manufacturing Survey.

and firm labour productivity. To deal with that shortcoming, other specialized papers applied instrumental variable estimation techniques in data sets covering several years.[19]

In the light of the discussion in Atrostic and Nguyen (2002) the preferred dependent variable for measuring labour productivity was total sales per employee.

A set of additional variables was used in each equation to control for the effect of foreign capital participation, for the multi-unit organizational aspect and also for unknown disparities in demand and supply across industries and regions. Information on firm age was used for verifying if among ICT users more experienced firms had superior labour productivity as compared with younger firms. Most regression estimates showed that businesses with foreign capital participation have on average 7 to 8 per cent higher sales. Firms belonging to multi-unit organizational structures have 2 to 4 per cent higher sales, presumably because they can more easily gain access to a larger pool of resources. Also, there appeared to be decreasing returns to scale: larger businesses had on average 0.5 to 3 per cent lower labour productivity given the set of controls. For a summary of the variables used see annex 2.

Regression results are valid only for the available sample of manufacturing businesses. Sampling weights corresponding to actual employment size, regions and industries were not used in the regression analysis and thus regression results cannot be extrapolated to the entire manufacturing sector.

To address concerns related to collinearity between regressors, annex 3 shows pair wise correlation coefficients for the first model specifications. They are all below the 0.8 threshold. As expected, a higher correlation of 0.67 is measured between computer presence and Internet access. However, when dropping one of the computer or Internet variables, estimated coefficients remain largely the same.

7. Results

Firstly, the study evaluated the relationship between computer, Internet and web presence and the value of sales per employee. The three measures of ICT were regarded as progressive steps adding to the complexity of ICT uptake since all firms using the Internet also had computers on their premises and all firms present on the web also had Internet access. Accordingly, estimates on the Internet factor are interpreted as additional to computer-related gains; similarly, web presence-related gains are complementary to those from Internet and computer use. Results are shown in table 4.

After controlling for a series of firm-specific economic characteristics, as well as industry and regional aspects of demand and supply, estimated results showed that firms with a combined use of computers, the Internet and the web had on average 21 per cent higher sales than firms without any of the ICTs considered. Among the three ICTs considered, computers contributed with 14 per cent, Internet access with 3 per cent and web presence with 4 per cent. Similar estimates were also obtained with the effective labour productivity variant of the model (table 4, second column). Atrostic and Nguyen (2005) estimated that in 1999 computer networks (such as the Internet, intranet, LAN, EDI, extranet or other) had a 5 per cent positive impact on labour productivity in a large sample of United States manufacturing firms. In comparison, the results derived in this study show that in Thailand computer presence was more closely associated with labour productivity than Internet connectivity.

[19] See for example, Atrostic and Nguyen (2002).

Table 4. Results for computer, the Internet and web presence

	OLS (White heteroskedasticity – consistent standard errors)	
Independent variables	Dependent variable: log (sales per employee)	Dependent variable: log (effective sales per employee)
	R^2 = 0.923877 Number of observations included: 5 877	R^2 = 0.893852 Number of observations included: 5 651
Computer presence	0.1359***	0.1346***
Internet access	0.0322*	0.0365*
Web presence	0.0418**	0.0491***

Note: The regression included controls for employment size, capital, costs incurred with materials, foreign capital participation, multi-unit firms and industry-specific characteristics. (Level of significance at *** 1 per cent, ** 5 per cent and * 10 per cent).

Studies based on developed country data rarely estimate the impact of computer presence on labour productivity because in many developed countries computer penetration rates in the business sector have already reached levels of as much as 95 per cent. However, in developing countries the share of firms that use at least one computer for business purposes has remained lower (60 per cent in manufacturing Thailand in 2002). Furthermore, data from the 2003 Manufacturing Survey in Thailand show that in absence of computers firms cannot access the Internet and establish web presence. This explains why in developing countries computer presence in firms is more closely related to economic performance than in developed countries.

Because the use of at least one computer seemed to account for a large share of the variation in sales per employee, it was interesting to estimate also the relationship between the intensity of computer use and labour productivity (tables 4 and 5). Results show that an increase of 10 per cent in the share of employees using computers is associated with 3.5 per cent higher sales per employee in Thai manufacturing firms. For the same variable, the estimated coefficient in Maliranta and Rouvinen (2003) was only 1.8 in a panel of Finnish firms (1998–2000). Since the variation in the intensity of computer use in Thailand was greater – with many firms not having computers – computer use was associated with larger differences in labour productivity in that country. Similarly, a 10 per cent improvement in the number of computers available per employee was correlated with a 4.5 per cent increase in sales per employee (table 5).

Computer intensity in firms, as captured by the number of physical computers per employee, can be interpreted as a measure of investment in computer capital. Similarly, the share of employees using computers also represents a proxy for computer capital investment, including investment in human capital and training for work with computers. As estimates in tables 5 and 6 show, Internet access contributed as a significant factor additional to computer intensity in explaining differences in labour productivity among firms. At the same time, when accounting for the intensity of computer use, it is noted that web presence is no longer significantly contributing to higher sales per employee. This suggests that a greater intensity of computer use and Internet access are factors facilitating the decision to establish web presence in the businesses analysed.

Both the labour productivity and the effective labour productivity models produced similar estimates for the overall use of computers, the Internet and the web in Thai manufacturing firms.

Table 5. Results for the share of employees using computers, the Internet and web presence

	OLS (White heteroskedasticity – consistent standard errors)	
Independent variables	Dependent variable: log (sales per employee)	Dependent variable: log (effective sales per employee)
	R^2 = 0.923260 Number of observations included: 5 863	R^2 = 0.893054 Number of observations included: 5 637
Share of employees using computers	0.3492***	0.3969***
Internet access	0.0561***	0.0582***
Web presence	0.0160	0.0229

Note: The regression included controls for employment size, capital, costs incurred with materials, foreign capital participation, multi-unit firms and industry-specific characteristics. (Level of significance at *** 1 per cent, ** 5 per cent and * 10 per cent).

Table 6. Results for the share of computers per employee, the Internet and web presence

	OLS (White heteroskedasticity – consistent standard errors)	
Independent variables	Dependent variable: log (sales per employee)	Dependent variable: log (effective sales per employee)
	R^2 = 0.923570 Number of observations included: 5 871	R^2 = 0.893028 Number of observations included: 5 645
Number of computers per employee	0.4466***	0.5185***
Internet access	0.0545***	0.0562**
Web presence	0.0147	0.0213

Note: The regression included controls for employment size, capital, costs incurred with materials, foreign capital participation, multi-unit firms and industry-specific characteristics. (Level of significance at *** 1 per cent, ** 5 per cent and * 10 per cent).

The study also estimated coefficients relating labour productivity to the different modalities of accessing the Internet (ISP subscribers, prepaid Internet package, Internet café, etc.), as well as to the different activities carried out on the Internet (e-mailing, information search, placing orders online, business promotion, etc.) and on the web (advertising own business, receiving orders online). However, results did not show significant differences in the way in which those factors were reflected in the value of sales per employee. More analysis would be needed to assess the role of the different modalities of Internet access and of the different activities carried out online in explaining firms' economic performance. This was beyond the scope of the present analysis.

In the second stage, the analysis aimed at identifying firms' characteristics that influenced the relationship between specific ICTs and labour productivity. For that purpose, the regression equation was slightly modified to estimate the effect[20] of ICT uptake in groups of firms with different size, age, geographic location and industry branches. The next subsection analyses whether firm size contributes to explaining the ICT–labour productivity relationship.

Differences between employment size groups

To analyse the implications of firm size in determining the ICT–productivity relationship, three employment size groups were considered: small firms (11 to 50 employees), medium-sized firms (51 to 200 employees) and larger firms (more than 200 employees). The groups chosen correspond to the national classification of Thailand into small, medium and large enterprises. Table 7 summarizes the results of three different empirical specifications. The estimation model shown in the first rows took into account information on the presence of computers in firms, Internet access and web presence. In the second and third models additional information was included on the intensity of computer use as measured by the share of employees using computers (the second specification) and the number of computers per employee (the third specification). Accordingly, results in the first model indicate that computer presence is correlated with higher productivity in all size groups but more so in large firms (more than 200 employees) and in small firms (the group with 11 to 50 employees in particular). Results further suggest that Internet access matters most to labour productivity in small firms, while web presence makes most difference in large firms. Overall, the link between ICT use and labour productivity is strongest in large firms. Medium-sized firms (51 to 200 employees) appear not to benefit as much from Internet access as small firms and also lag behind large firms in terms of gains from web presence.

The second and third models in table 7 show the estimated relationship between the intensity of computer use and productivity and confirm the results obtained with the first model. However, in accounting for the intensity of computer use, web presence no longer had a significant effect.

[20] Further econometric tests show that differences between the group estimates are not systematically different in all cases.

This indicates that in general firms with greater intensity of computer use also had web presence. In all the size groups most productivity gains from ICT are associated with the intensity of computer use. A 10 per cent higher share of employees using computers leads on average to an estimated 4 per cent higher sales in small firms, 1.7 per cent in medium-sized firms and 3.8 per cent higher sales per employee in large firms. Similarly, 10 per cent more computers per employee are correlated with 4.5 per cent higher sales per employee in small firms, 2.5 per cent in medium-sized and respectively 5.2 per cent in large firms. As shown before, access to Internet seems to make most difference in small firms where it is correlated with 8 per cent higher productivity, additional to gains from the use of computers. Estimates taking into account the use of computers indicate again that medium-sized firms did not achieve significantly higher productivity in correlation with the use of Internet and web presence. Additional analysis showed that among the group of small businesses, firms with 25 to 50 employees seemed to have higher gains from ICTs.

Table 7. Results by employment size

OLS (White heteroskedasticity – consistent standard errors) Dependent variable: log (sales per employee)			
	Small firms (11 to 50)	**Medium-sized firms (51 to 200)**	**Large firms (>200)**
Computer presence	0.1365***	0.1034***	0.1806***
Internet access	0.0528**	0.0331	-0.0297
Web presence	0.0460	0.0432	0.0455*
R^2 = 0.923573, Number of observations included 5873			
Share of employees using computers	0.4014***	0.1723**	0.3821***
Internet access	0.0809***	0.0391	0.0082
Web presence	0.0189	0.0310	0.0157
R^2 = 0.922656, Number of observations included 5858			
Number of computers per employee	0.4453***	0.2549**	0.5166***
Internet access	0.0839***	0.0342	0.0074
Web presence	0.0183	0.0314	0.0136
R^2 = 0.923411, Number of observations included 5867			

Note: The regression included controls for employment size, capital, costs incurred with materials, foreign capital participation, multi-unit firms and industry-specific characteristics. (Level of significance at *** 1 per cent, ** 5 per cent and * 10 per cent).

Differences between age groups

Several studies reviewed in the previous section found that firm age was an additional factor explaining how much enterprises gain from ICT. To analyse whether the same effect appeared in manufacturing Thailand, this study grouped businesses according to their founding year and hence experience in the market. There are three groups with an equal number of firms: young (founded between 1997 and 2002), middle-aged (founded between 1991 and 1996) and old (founded before 1991). The applied estimation technique was the same as in the case of firm size. Results are shown in table 8 with the first model showing the effect of computer presence, Internet access and web in the different age groups, while in the second and third models the analysis also takes into account the intensity of computer use.

In young firms computer presence is associated with the greatest value of gains in terms of sales per employee, which suggests that young firms use computers more effectively. However, older firms seem to gain most from the combined use of computers, the Internet and the web. In older firms the presence of computers also matters, albeit less than in the younger ones, while there is an additional contribution to productivity from Internet access and the web.

With regard to accounting for the intensity of computer use, results indicate again that for larger firms, with more experience in the market, there was a stronger correlation between ICT uptake and labour productivity. Results also show that younger firms with a lower intensity of computer use seem to achieve higher sales per employee when they have access to the Internet.

Table 8. Results by firm age

OLS (White heteroskedasticity – consistent standard errors) Dependent variable: log (sales per employee)			
	Young firms (1997-2002)	**Middle-aged firms (1991-1996)**	**Old firms (<1991)**
Computer presence	0.1729***	0.1498***	0.0902***
Internet access	0.0313	0.0144	0.0484*
Web presence	0.0372	0.0220	0.0613**
R^2 = 0.924005, Number of observations included: 5 877			
Share of employees using computers	0.1786	0.4286***	0.3713***
Internet access	0.1203***	0.0449*	0.0260
Web presence	0.0206	-0.0021	0.0323
R^2 = 0.923348, Number of observations included: 5 863			
Number of computers per employee	0.2500*	0.5188***	0.4922***
Internet access	0.1146***	0.0465*	0.0236
Web presence	0.0226	-0.0039	0.0292
R^2 = 0.923653, Number of observations included: 5 871			

Note: The regression included controls for region and industry-specific characteristics. (Level of significance at *** 1 per cent, ** 5 per cent and * 10 per cent).

Both firm age and employment size seem to influence the magnitude of the relationship between ICT use and labour productivity. Larger and more experienced firms appear to gain more from the combined use of the three specific ICTs analysed here (computers, Internet and web). The presence of computers and the intensity of computer use contribute substantially to explaining those differences. However, in smaller and younger firms Internet access matters more in the sense that a lower intensity of computer use can be compensated for by use of the Internet. Chinn and Fairlie (2006) analysed the factors leading to higher computer and Internet penetration rates and show that income has a greater influence on decisions to acquire computers than does Internet access. Small and young firms with computers may find it easier to buy Internet access rather than additional computers. This study suggests that that small firms with at least one computer gain most from Internet access, while young firms use computers more effectively.

Regional and industry characteristics also have a bearing on the strength of ICT's impact on firm performance. These are further explained in the next two subsections.

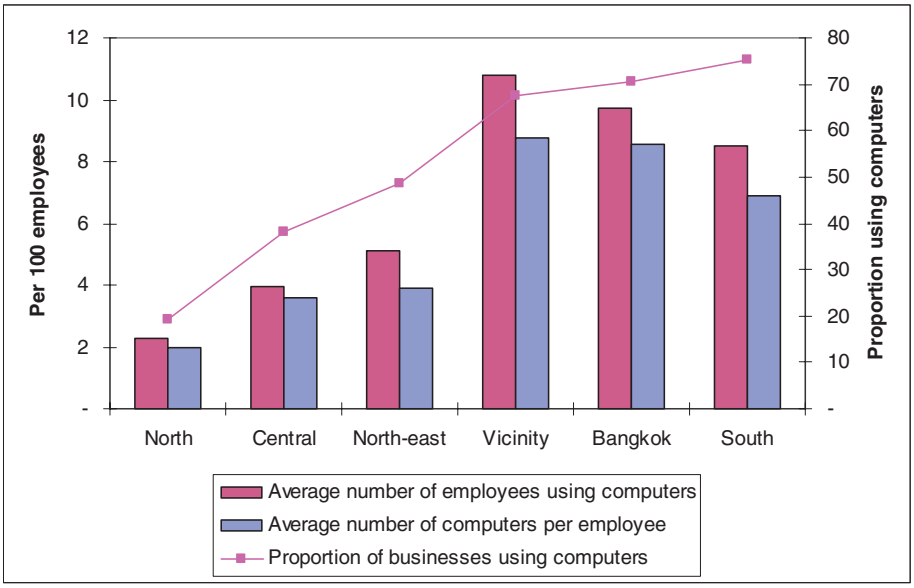
Regional differences

Owing to factors such as infrastructure, labour force training and qualifications and market size, firms located in different geographical regions use ICTs differently.

Dominated by larger manufacturing firms, the south had the highest share of computer-equipped firms and a relatively high intensity of computer use. The northern region had different characteristics: more small enterprises, fewer firms with computers and a more reduced intensity of computer use (see charts 19 and 20).

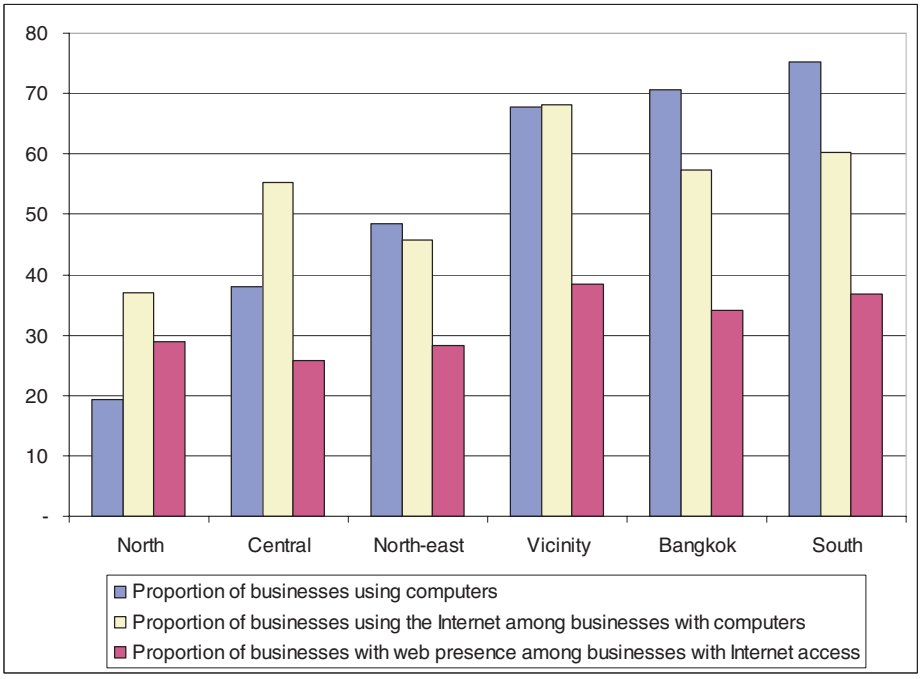
In terms of Internet access, Bangkok and the southern region had the two highest Internet penetration rates. Not surprisingly, this region, together with Bangkok, has the highest proportion of ISP regular subscribers. Access through Internet cafés and prepaid Internet packages is more popular among manufacturers located in the north. However, in the north and the centre, there is a greater proportion of businesses with computers connected to the Internet. For example, in the north only 20 per cent of businesses have computers but among those with computers almost 40 per cent have also acquired Internet access. This confirms that the use of computers is an important source of differentiation among firms located in different geographical regions. Among businesses with computers, the proportion of businesses using the Internet and present on the web varied less across regions (chart 20).

Chart 19. Use of computers in the manufacturing sector by regions, 2003



Source: Thai Manufacturing Survey 2003, businesses with more than 10 employees.

Chart 20. Proportion of businesses using computers, Internet and web presence in the manufacturing sector by regions, 2003



Source: Thai Manufacturing Survey 2003, businesses with more than 10 employees.

Table 9 shows the results of two different models estimating the relationship between ICT use and labour productivity in businesses from different regions. The first one takes into account computer presence, Internet access and web presence, while the second one also considers the intensity of computer use as measured by the share of employees using computers.

Both sets of results confirm that computers are more important among the ICTs considered here in accounting for variations in sales per employee. That is shown by the highly significant coefficients for presence of computers and share of employees using computers. For firms located in the Central region, web presence seems to matter more than in other regions. In Bangkok higher sales per employee are generated in businesses with computers and Internet access. In the vicinity of Bangkok similar results apply, but Internet access is relatively more important. In the north, sales per employee appear to be correlated much more with computer use than with the Internet and the web. The negative coefficient estimated for web presence shows that in the northern region businesses with computers, the Internet and the web have lower sales than businesses equipped only with computers. This finding can be explained by the fact that there is a very small share of web-present firms in the north (only 2 per cent) and that the use of web presence leads to fewer efficiency gains in this region than in others. A similar problem seems to occur in the north-east for the web-present firms, but the estimated negative effect is much smaller and not significant. In the south higher labour productivity is recorded in the most computer-intensive firms.

Table 9. Results by geographical region

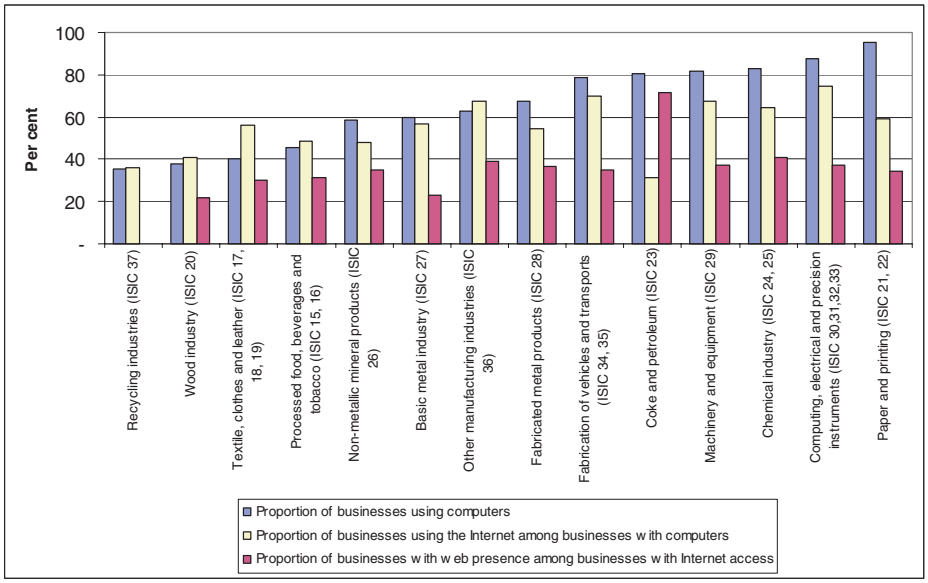
OLS (White heteroskedasticity – consistent standard errors) Dependent variable: log (sales per employee)						
	R^2 = 0.924005 Number of observations included: 5 877			**R^2 = 0.923348 Number of observations included: 5 863**		
	Computer presence	Internet access	Web presence	Share of employees using computers	Internet access	Web presence
Bangkok	0.1298***	0.0892*	0.0254	0.4735***	0.0844**	-0.0007
Vicinity	0.1411***	0.0511	0.0731*	0.2037**	0.0852***	0.0496
Central	0.1553***	0.0121	0.1533**	0.2851	0.0730**	0.1372**
North	0.1921***	0.0302	-0.1720**	0.5234**	0.0954	-0.2187**
North-east	0.1187***	0.0669	-0.0101	0.2029	0.0865	-0.0394
South	0.1436***	0.0236	0.0400	0.5642***	0.0285	0.0089

Note: The regression included controls for employment size, capital, costs incurred with materials, foreign capital participation, multi-unit firms and industry-specific characteristics. (Level of significance at *** 1 per cent, ** 5 per cent and * 10 per cent).

Industry differences

In order to simplify the analysis, industries were classified into 14 broader categories of manufacturing activity (for reference purposes ISIC Rev. 3 codes are provided in parentheses). As expected, ICT use also varied considerably across industries (chart 21). Measures of ICT uptake in particular sectors of activity are a reflection of industry characteristics and the degree to which particular business types are able to integrate computers, the Internet and the web in their production process. The computing, electrical and precision instruments sector emerges as the most frequent user of the Internet and web presence. The paper and printing industry has the highest share of businesses with computers but lags behind regarding the use of the Internet and web presence. The chemical industry and machinery and transport equipment follow closely behind with high penetration rates for computers, the Internet and the web. In coke and petroleum an unusually high share (70 per cent) of the firms with computers and the Internet also find it useful to establish web presence. Computerized firms in the group of other manufacturing industries (such as furniture, jewellery and musical instruments) and textiles, clothing and leather are connected to the Internet in a higher proportion than in other sectors. This indicates that Internet access is considered more relevant in those industries than, for example, in coke and petroleum.

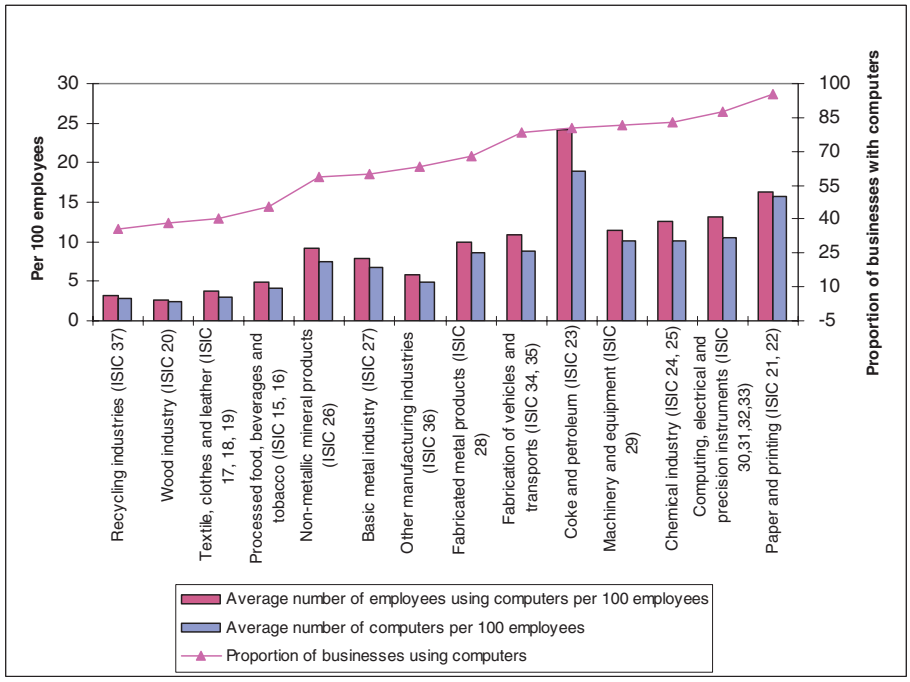
Chart 21. Proportion of businesses using computers, Internet and web presence in the manufacturing sector by industry, 2003



Source: 2003 Manufacturing Survey in Thailand, firms with more than 10 employees.

Chart 22 shows information regarding the intensity of computer use in businesses. Coke and petroleum stands out as the industry with the highest intensity of computer use. The least computer-intensive sectors are the recycling industry but also the wood industry, textiles, clothing and leather, the processed food, beverages and tobacco industry. Typical of the last three manufacturing sectors was the very high share of small businesses.

Chart 22. Use of computers in the manufacturing sector by industry, 2003



Source: Thai Manufacturing Survey 2003, businesses with more than 10 employees.

Table 10 shows for comparison the results of two empirical exercises: one taking into account computer presence, the Internet and the web, and the other estimating the importance of the intensity of computer use as captured by the share of employees using computers. Estimation results identified four sectors where the use of particular ICTs was correlated with higher than average sales per employee: machinery and equipment, basic metal industry, computing, electrical and precision instruments and processed food, and beverages and tobacco.

The combined use of computers, the Internet and the web was associated with the highest gains in:

- Machinery equipment;
- Basic metal industry; and
- Computing, electrical and precision instruments.

Internet access seemed to be more strongly related to higher sales per employee in:

- Machinery equipment;
- Computing, electrical and precision instruments;
- Processed food, beverages and tobacco; and
- Fabricated metal products

Web presence seemed to add more to gains from computers and the Internet in:

- Machinery equipment;
- Basic metal industry; and
- Processed food, beverages and tobacco.

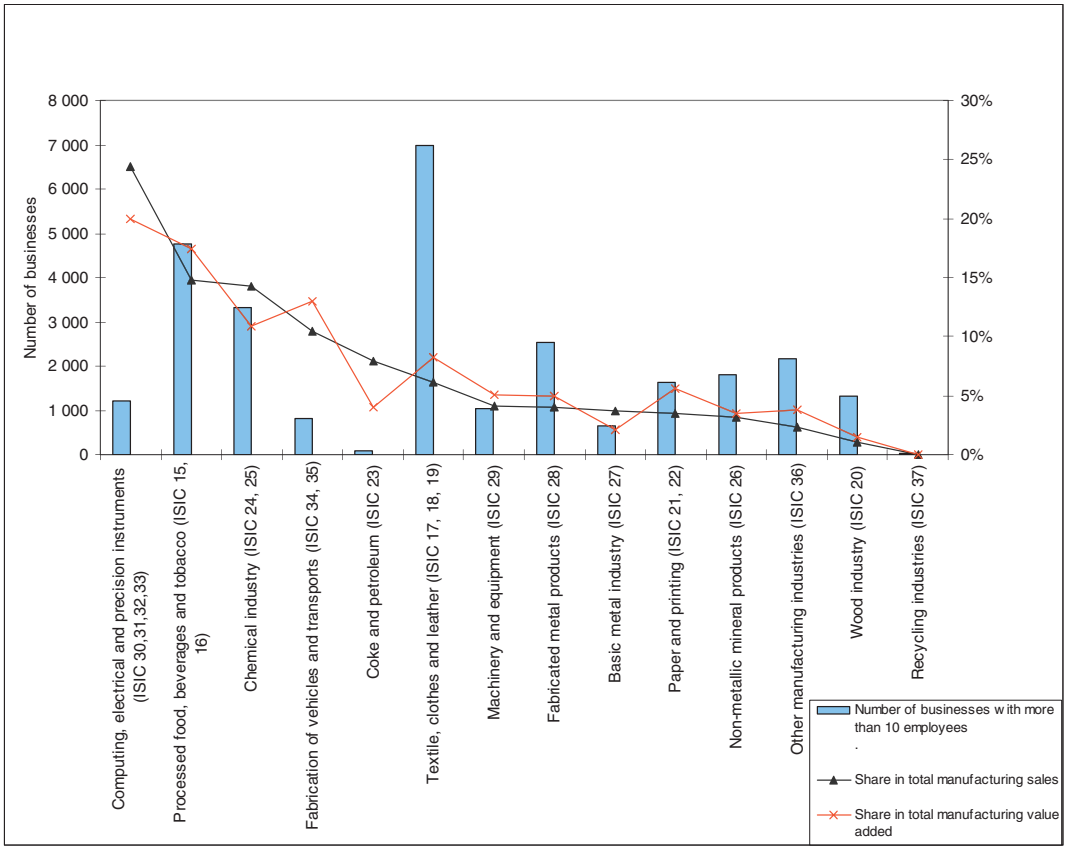
Table 10. Results by industry affiliation

OLS (White heteroskedasticity – consistent standard errors) Dependent variable: log (labour productivity)						
	R^2 = 0.922725 Number of observations included: 5 877			**R^2 = 0.922234 Number of observations included: 5 863**		
	Computer presence	Internet access	Web presence	Share of employees using computers	Internet access	Web presence
Processed food, beverages and tobacco (ISIC 15, 16)	0.1409***	0.0492*	0.0745*	0.4735***	0.0739**	0.0486
Textile, clothing and leather (ISIC 17, 18, 19)	0.1912***	0.0222	-0.0219	0.3728**	0.0609*	-0.0369
Wood industry (ISIC 20)	0.1354***	0.0563	0.0443	1.0008**	0.1056	0.0504
Paper and printing (ISIC 21, 22)	0.1357***	0.0132	0.0635	0.3009**	0.0172	0.0044
Coke and petroleum (ISIC 23)	0.2550**	-0.0038	-0.1637	0.5608***	-0.1150	-0.3177
Chemical industry (ISIC 24, 25)	0.1148***	-0.0128	0.0189	0.3487***	0.0049	-0.0201
Non-metallic mineral products (ISIC 26)	0.1123***	0.0285	0.0331	0.1943	0.0431	-0.0222
Basic metal industry (ISIC 27)	0.1558***	0.0775	0.1672**	0.2751	0.0764	0.1202
Fabricated metal products (ISIC 28)	0.1810***	0.0638*	0.0522	0.5150***	0.0865***	0.0298
Machinery and equipment (ISIC 29)	0.2090***	0.0998**	0.1619*	0.6667***	0.1203***	0.1384
Computing, electrical and precision instruments (ISIC 30, 31, 32, 33)	0.2283***	0.0745**	0.0292	0.4350***	0.0819***	-0.0061
Fabrication of vehicles and transports (ISIC 34, 35)	0.1134***	0.0315	0.1038	0.3983**	0.0488	0.0734
Other manufacturing industries (ISIC 36)	0.0744**	-0.0057	-0.0055	0.3118	0.0448	-0.0006
Recycling industries (ISIC 37)	-	-	-	-	-	-

Note: The regression also included controls for employment size, capital, costs incurred with materials, foreign capital participation, multi-unit firms, and region-specific characteristics. (Level of significance at *** 1 per cent, ** 5 per cent and * 10 per cent).

Chart 23 shows the contribution of the different industry branches to revenue and value added in manufacturing Thailand. The computing, electrical and precision instruments industry is the most important contributor to sales and value added in the Thai manufacturing sector. This industry is part of the Thai ICT-producing sector and has some of the highest Internet and web coverage. Estimation results indicate that in this sector the presence of computers and Internet access leads to as much as 30 per cent higher labour productivity on average.

Chart 23. Share of manufacturing industry sectors in sales and value added in Thailand, 2003



Note: The 23 ISIC Rev.3 sectors were grouped into 14 broader manufacturing industry categories.
Source: Thai Manufacturing Survey 2003, businesses with more than 10 employees.

The processed food, beverages and tobacco sector is the second highest contributor to value added in Thai manufacturing. This light industry sector is characterized by considerably low use of computers, the Internet and the web as compared to other sectors. However, estimation results show that productivity differentials within this industry were strongly correlated with the use of the Internet (4.9 per cent) and web presence (7.5 per cent). If demand for food, beverages and tobacco remains favourable, there is scope for producers to increase productivity as they start using ICTs more frequently.

Last but not least, estimates showed that for the machinery equipment and the basic metal industries web presence seems to make the most difference. Firms in those industries with web presence have on average 16 per cent higher sales per employee than firms with just computers and Internet access. A more detailed study of how web presence is used in the machinery equipment and basic metal industries in Thailand would help further understand why these firms have higher labour productivity.

8. Conclusions and policy recommendations

The main objective of this study was to analyse the economic impact of ICT use in the Thai business sector. General trends on ICT use in business show that from 2004 to 2006 the proportion of businesses using computers has increased steadily on a general level, with faster growth among small businesses with 26 to 50 employees. Among large firms, almost 100 per cent already had computers in 2004, but there has been an important increase in the number of computers available per firm in this group. One fifth of the urban firms with more than 10 employees did not use computers on their premises, which is a larger share than in a number of other Asian economies such as Hong Kong (China), the Republic of Korea and Singapore.

The data also revealed that businesses using the Internet regularly in their work have seen their share growing faster from 2004 to 2006, to reach 56 per cent. Such growth was apparent in a large number of firms with 11 to 100 employees and went hand in hand with a substantial shift from dial line narrowband connections to faster DSL broadband connections. The sectors with the highest Internet penetration rate in business belong to the services industry: computer and related activities and hospitals. Web presence, closely related to regular Internet access also increased from 2004 to 2005 but was followed by a decline in 2006 reflecting a 3 per cent drop in the number of large businesses in the Thai market. Only 15 per cent of the small businesses (11 to 25 employees) are present on the web, with small changes over time. Web presence is used most frequently in computer and relates services, in hospitals and in real estate businesses, mainly for marketing products and as an inquiry/contact facility. Firms receiving orders online make up for 7 per cent of the business sector.

Results of the productivity analysis find that computer use, Internet access and web presence are associated with significantly higher sales per employee. In comparison with similar analyses carried out in developed countries, this project finds that the use of computers more than the Internet and the web presence, is a key factor in explaining higher productivity in firms. In developed countries the penetration rates of basic ICTs such as computers are already close to saturation levels and therefore computer presence is nearly used by all businesses (of more than 10 employees). However in developing countries there is a lower share of businesses that use at least one computer.[21]

Variation in the intensity of computer use in Thailand was also reflected in higher productivity gains. Estimates show that a 10 per cent increase in the share of employees using computers was correlated with 3.5 per cent higher labour productivity, more than the 1.8 per cent estimated impact in a sample of Finnish manufacturing firms and the 2.8 per cent for Finnish services firms. In the theoretical setting considered, computers bring value to businesses both through their intrinsic characteristics such as processing and storage capacity and as necessary means for acquiring a superior complexity of ICT use such as Internet access and web presence.

Internet access and web presence are also found to be correlated with higher sales per employee in Thailand, with a similar coefficient to that estimated in other studies. For example, Atrostic and Nguyen (2005) estimated that computer networks brought a 5 per cent positive net effect to firm labour productivity in the United States after accounting for the contribution of computer capital. Similarly, results derived here suggest that Thai firms with access to Internet had on average 4 to 6 per cent higher sales per employee, additional to the effect of computers. Estimated results also indicate that Internet use matters more in small firms, located in Bangkok and the neighbouring region, while web presence was correlated with higher labour productivity gains among large businesses located in the central region.

This study also quantified differences in the ICT-labour productivity relationship across employment size groups, firm age, regional geographical location and industry affiliation. This type of estimated coefficients aimed at indicating the areas where the use of specific ICTs is more strongly correlated with superior economic performance. Among Thai manufacturing businesses

[21] See chapter 1 of the Information Economy Report 2007-2008 (UNCTAD, 2007).

the groups which seem to benefit from a stronger ICT -labour productivity relationship are the larger and medium-sized, more experienced firms located in the Central region and also in Bangkok and its vicinity. Younger firms however tended to use computers more effectively, while in smaller firms Internet access makes a big difference. Further case study evidence is needed in order to establish how ICTs contribute to improved economic performance in specific fields and how this efficiency can be scaled up to other groups of enterprises. The estimates derived in this study indicate the need to support the small and newly founded businesses, particularly by enhancing access to Internet and facilitating their presence on the web. On a regional scale, small and young businesses dominate the business sector in the north and north-east of the country and therefore these regions should be a target of public programmes to facilitate ICT use.

Furthermore, data show that in developing countries exporting firms use the Internet and the web more frequently than domestic producers, largely motivated by the need to access information and consumers in foreign markets. This could be explained by the fact that developed countries have the highest population of potential buyers and suppliers using the Internet and which are present on the web (Clarke and Wallsten, 2004). Policies aiming to facilitate the creation of local content available on the Internet could help to bridge this gap.

The ICT Surveys find that a large proportion of the firms that do not use ICTs on their premises identify as most important barriers the lack of perceived benefits and ICTs being inappropriate or unnecessary for their business. This finding calls for policy action to raise awareness about the benefits businesses can achieve by using ICTs, especially among small and medium-sized businesses where the proportion of firms refraining from ICT use is higher.

In the context of raising awareness, it is critical to continue measuring and monitoring the extent to which the business sector uses ICTs and to publish regularly updated statistical information. In-depth data analysis can provide additional evidence on how ICT use in business can translate in better economic performance. More technical information on how businesses of a particular industry use ICTs can help producers understand what is needed to improve the quality of products and better respond to demand. For example, one could inquire why the proportion of retail businesses with access to Internet and web presence remains low in Thailand as compared to the same sector in the United States and identify strategies of scaling up the use of these technologies for greater production efficiency.

Annex 1. Summary of literature on ICTs and productivity at the firm level

Author	Dataset	Dependent variable	ICT variables used	Type of regression	Impact of ICT variables on labour productivity
Atrostic & Nguyen (2002)	US manufacturing panel, 3 years (1992, 1997 and 1999) 38 000 firms	Sales per employee	Dummy variable for presence of computer networks (such as Internet, intranet, LAN, EDI, extranet or other).	Cobb–Douglas production function with 3 factors (labour, capital and materials). Control variables: size of establishment instead of number of employees, skill mix, multi-unit firm, industry.	5 per cent from presence of computer networks.
Atrostic & Nguyen (2005)	US manufacturing, 1999	Sales per employee	Computer capital and computer networks dummy (as above).	Cobb–Douglas production function with 4 factors (labour, ordinary capital, computer capital and materials). Control variables: size of establishment instead of number of employees, firm age, skill mix, multi-unit firm, industry.	5 per cent from presence of computer networks and 12 per cent for computer capital.
Maliranta & Rouvinen (2003)	Finland panel; 3 years (1998–2000) Manufacturing and services separately with 1 500 firms each. ICT-producing sector considered separately.	Output per employee	Share of computer-equipped labour, share of Internet-using labour, share of labour using LAN at work.	Cobb–Douglas production function with 2 factors (labour and capital). Control variables: skill mix and firm age.	A 10 per cent increase in computer-equipped labour results in 1.8 per cent higher labour productivity in manufacturing and 2.8 per cent in services. A 10 per cent increase in Internet-equipped labour results in 2.9 per cent higher labour productivity in services (negative estimated impact in manufacturing). A 10 per cent increase in the share of labour using LAN results in 2.1 per cent higher labour productivity in manufacturing (no significant impact in services).
Maliranta & Rouvinen (2006)	Finland, 2001, 2 358 services and manufacturing firms	Output per employee	Share of workforce using desktops, laptops, wireline access to Internet (LAN) and wireless access to Internet (WLAN).	Cobb–Douglas production function with 2 factors (labour and capital). Control variables: skill mix, firm age and gender participation in labour force.	9 per cent labour productivity gains from a higher share of labour force using computers (desktop). Additional 32 per cent from computer portability.

Author	Dataset	Dependent variable	ICT variables used	Type of regression	Impact of ICT variables on labour productivity
					Additional 14 per cent from wireline Internet connectivity. Additional 6 per cent from wireless connectivity.
Hagén & Zeed (2005)	Sweden, 2002 2 752 firms with 10 employees or more (manufacturing and services together)	Value added per employee	Share of employees using computers, dummy variable for access to broadband, a composite ICT index.	Cobb–Douglas production function with 2 factors (labour and capital). Control variables: size of establishment instead of number of employees, skill mix, ownership, perceived lack of IT competence and industry.	A 10 per cent increase in computer-equipped labour results in 1.3 per cent higher labour productivity. 3.6 per cent labour productivity gains from broadband. Positive but decreasing impact of adopting an increasing number of ICT solutions.
Criscuolo & Waldron (2003)	UK manufacturing panel, 2 years (2000, 2001) 5 500 firms	Gross output per employee and value added per employee	Dummy variables for e-commerce (either placing or receiving orders online)	Cobb–Douglas production function with 3 factors (labour, capital and materials). Control variables: region, ownership, firm age, industry and year fixed effects.	Between 7 and 9 per cent labour productivity gains from placing orders online. Receiving orders online has negative effects (-5 per cent).
Farooqui (2005)	UK panel, 4 years (2000–2003); 2 277 manufacturing firms and 3 490 services firms taken separately	Value added per employee	Hardware capital stock, software capital stock, share of employees using ICT (computer and Internet), spending on telecommunication services, e-commerce (placing and receiving orders online).	Cobb–Douglas production function with 2 factors (labour and capital). Control variables: firm age, ownership, region and industry.	A 10 per cent increase in the share of employees using computers results in 2.1 per cent higher labour productivity in manufacturing and 1.5 per cent in services. A 10 per cent increase in the share of employees using Internet results in 2.9 per cent higher labour productivity in manufacturing (no significant impact on services).
Brynjolfsson & Hitt (2002)	US manufacturing panel, 8 years (1987–1994); 527 large firms	Total factor productivity growth	Computer capital	Total factor productivity growth framework.	Gain in multifactor productivity over time from 1.9 per cent for 1 year differences to 5.3 per cent for 7 year differences in computer capital investments.

Annex 2. Summary of the variables used in the regression analysis

Variable name	Definition
Log (sales per employee)	Natural logarithm of the amount of sales per employee calculated in current Baht per employee (only 2002 data considered).
Log (materials per employee)	Natural logarithm of spending on materials per employee calculated in current Baht per employee (only 2002 data considered).
Log (capital per employee)	Natural logarithm of the book value per employee calculated in current Baht per employee (only 2002 data considered).
Log (labour)	Natural logarithm of the total number of employees in a business.
Foreign capital participation	Dummy variable taking on value 1 if the business has foreign capital participation and 0 otherwise.
Multi-unit firm	Dummy variable taking on value 1 if the business is a branch or headquarters of a larger enterprise and 0 otherwise.
Bangkok, Vicinity, Central, North, North-east, South	For each region, dummy variable taking on value 1 if the business is located within a certain geographical region and 0 otherwise.
Processed food, beverages and tobacco (ISIC 15, 16), Textile, clothing and leather (ISIC 17, 18, 19), Wood industry (ISIC 20), Paper and printing (ISIC 21, 22), Coke and petroleum (ISIC 23), Chemical industry (ISIC 24, 25), Non-metallic mineral products (ISIC 26), Basic metal industry (ISIC 27), Fabricated metal products (ISISC 28), Machinery and equipment (ISIC 29), Computing, electrical and precision instruments (ISIC 30, 31, 32, 33), Fabrication of vehicles (ISIC 34, 35), Other manufacturing industries (ISIC 36), Recycling industries (ISIC 37).	For each industry, dummy variable taking on value 1 if the main activity of the business has been classified as belonging to a specific sector and 0 otherwise.
Computer presence	Dummy variable taking on value 1 if the business has at least one computer and 0 otherwise.
Internet access	Dummy variable taking on value 1 if the business has access to Internet and 0 otherwise.
Web presence	Dummy variable taking on value 1 if the business has web presence either on its own website or on the website of a different business and 0 otherwise.
Share of employees using computers	Proportion of employees using computers per total number of employees.
Number of computers per employee	Number of computer per total number of employees.
Data source: 2003 Manufacturing Survey	

Annex 3. Correlation coefficients between the regressors used in the analysis

	Log (materials per employee)	Log (capital per employee)	Log (labour)	Foreign capital participation	Multi-unit firm	Computer presence	Internet access	Web presence
Log (materials per employee)	1.00	0.57	0.44	0.31	0.33	0.58	0.45	0.28
Log (capital per employee)	0.57	1.00	0.15	0.24	0.20	0.34	0.27	0.18
Log (labour)	0.44	0.15	1.00	0.40	0.43	0.65	0.60	0.41
Foreign capital participation	0.31	0.24	0.40	1.00	0.23	0.35	0.44	0.27
Multi-unit firm	0.33	0.20	0.43	0.23	1.00	0.37	0.37	0.29
Bangkok	0.14	-0.00	0.09	-0.00	0.02	0.14	0.11	0.07
Vicinity	0.16	0.16	0.11	0.16	0.12	0.12	0.13	0.08
Central	-0.19	-0.10	-0.10	-0.07	-0.07	-0.12	-0.09	-0.07
North	-0.08	-0.08	-0.17	-0.09	-0.04	-0.12	-0.12	-0.08
North-east	0.24	0.14	-0.13	0.07	0.04	0.20	0.15	0.10
Processed food, beverages and tobacco (ISIC 15, 16)	0.00	0.01	-0.05	-0.10	-0.01	-0.12	-0.12	-0.07
Textile, clothing and leather (ISIC 17, 18, 19)	-0.21	-0.18	-0.00	-0.04	-0.02	-0.10	-0.06	-0.03
Wood industry (ISIC 20)	-0.05	-0.06	0.01	-0.04	-0.01	-0.02	-0.04	-0.03
Paper and printing (ISIC 21, 22)	0.06	0.07	-0.02	-0.01	-0.02	0.14	0.05	0.02
Coke and petroleum (ISIC 23)	0.07	0.05	0.01	0.02	0.03	0.03	-0.00	0.01
Chemical industry (ISIC 24, 25)	0.12	0.07	0.09	0.08	0.08	0.12	0.11	0.07
Non-metallic mineral products (ISIC 26)	0.01	0.06	-0.00	-0.04	0.01	0.00	-0.03	-0.01
Basic metal industry (ISIC 27)	0.05	0.03	0.02	0.01	0.02	0.01	0.00	-0.01
Fabricated metal products (ISISC 28)	0.04	0.05	-0.07	-0.01	-0.03	0.00	0.00	-0.01
Machinery and equipment (ISIC 29)	0.07	0.05	0.02	0.04	0.02	0.07	0.06	0.04
Computing, electrical and precision instruments (ISIC 30, 31, 32, 33)	0.08	0.04	0.06	0.15	-0.00	0.09	0.12	0.07
Fabrication of vehicles (ISIC 34, 35)	0.06	0.05	0.01	0.07	-0.01	0.04	0.04	0.03
Other manufacturing industries (ISIC 36)	-0.10	-0.11	-0.00	0.01	-0.01	-0.03	0.01	0.02
Computer presence	0.58	0.34	0.65	0.35	0.37	1.00	0.67	0.36
Internet access	0.45	0.27	0.60	0.44	0.37	0.67	1.00	0.53
Web presence	0.28	0.18	0.41	0.27	0.29	0.36	0.53	1.00

Annex 3. Correlation coefficients between the regressors used in the analysis *(continued)*

	Log (materials per employee)	Log (capital per employee)	Log (labour)	Foreign capital participation	Multi-unit firm	Internet access	Web presence
Share of employees using computers	0.40	0.32	0.22	0.29	0.19	0.44	0.29
Number of computers per employee	0.37	0.30	0.17	0.27	0.15	0.41	0.27

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