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China in the international fragmentation of production: Evidence from the ICT industry

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Abstract

This paper investigates the position of China in the international fragmentation of production in the ICT industry, the most dynamic and globally dispersed sector in the world economy. The evidence shows that during the 1990s China dramatically increased its market shares in ICT products and now ranks among the top three world exporters. Moreover, China has upgraded from mere assembly of imported inputs to the manufacturing of high-tech intermediate goods. As a result, import dependence has declined and the domestic value added of exports has increased. This supports the hypothesis that industrial upgrading occurred in some tradable sectors through technological learning associated with processing trade. Therefore, a pattern of specialization initially dominated by processing trade could be favourable to a country's long-term development, to the extent that entering at the lower end of high-tech sectors is promotive of catching up in more sophisticated technology-intensive production.

JEL Classification: F020, F14, L63, N60

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1. Introduction

Since the early 1980s, the integration of China into the world economy has been increasing dramatically: the country has expanded its foreign trade at a compound annual growth rate of 17.5 per cent. At the same time it has diversified its export structure: initially a producer of labour-intensive goods in traditional sectors, during the 1990s China upgraded to higher forms of processing than footwear and apparel industries that dominated in the 1980s and in the first part of the 1990s. By the late 1990s, not only had the skill level of exports increased, but the ratio of value added in export processing almost doubled from under 20 per cent in 1993-1994 to 35 per cent in the late 1990s (due to both higher wage levels required by more skilled labour and to the displacement of imports by locally produced parts and components) (Lardy, 2002).

China's outstanding performance in world markets is mostly due to an increased involvement of the country in international fragmentation of production, i.e. the splitting up of the value chain into different stages carried out by firms in different countries. Indeed, China's foreign trade expansion in the 1990s relied mainly on processing operations: exports resulting from assembly and processing of imported parts and components made up 46 per cent of Chinese exports in 1992 and 55 per cent in 1996, and since then have represented more than half of Chinese exports (Lemoine and Ünal-Kesenci, 2002).

A great majority of this trade performance is due to an impressive increase of electronics trade: in 1985-98, China recorded the world highest annual average growth rate of electronics exports (52.8 per cent), almost four times higher than the average

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world rate (13.5 per cent)(Tung, 2003). A sectoral breakdown of the electronics sector shows that the ICT industry (i.e. Office machines, IT products, Telecom products and Semiconductors) accounted for the highest export and import shares if compared to other sub-sectors in electronics (43 per cent and 51 per cent respectively) (Tung, 2003).

This expansion of processing activities in the ICT industry poses interesting questions. Which are the consequences on China's specialization profile over time? To what extent is China still mainly an assembly country, specialized in traditional labour-intensive sectors (textile, clothing and apparel) and in labour-intensive stages of production in otherwise advanced industries? And to what extent has it developed new production capacities in skill- and technology-intensive stages of production in sectors such as ICT? And, finally, how far has processing trade evolved from mere assembly of imported inputs to local production of intermediate skill- and technology- intensive products? To the extent that empirical evidence supports these questions, this would suggest that an industrial upgrading occurred in some tradable sectors of the Chinese economy through technological learning associated with processing trade.

This paper tries to answer these questions through an empirical analysis of the position of China in international production fragmentation in the ICT industry, based on five-digit SITC trade data from UN Comtrade database. This data set allows for a very detailed and accurate disaggregation of ICT equipment, parts, components and accessories.[2] Our findings show that during the 1990s China dramatically increased its market shares in ICT products and now ranks among the top three world exporters. Moreover, China has upgraded from mere assembly of imported inputs to the manufacturing of high-tech intermediate goods. This supports the hypothesis of industrial upgrading through technological learning via processing of imported inputs.

The paper is organized as follows. Section 2 provides on overview of some recent theoretical and empirical literature on the role of processing trade as a channel for technological learning and industrial upgrading. Section 3 presents evidence on the international fragmentation of production in the ICT industry during the 1990s and on the position of China in ICT production processes. Section 4 studies the evolution of China's specialization profile by sector. Section 5 concludes.

2. Processing trade and industrial upgrading

The idea of international trade as a transmission mechanism that links a country's productivity gains to economic development in its trade partners has been firstly put forward by the new theory of economic growth (for a review see Grossman and Helpman, 1994). The framework for this paper is based on a line of such research that explored the relationship between trade patterns and industrial upgrading. A first direction of research includes theoretical studies showing that a higher aggregate trade volume is assumed to have a positive effect on productivity growth as it spurs innovation and imitation (see Grossman and Helpman, 1991 as a benchmark and Helpman, 1992). At a sectoral level, there is empirical evidence that trade openness enhances productivity gains and industrial catching-up in technology-intensive industries (Stehrer and Wörz, 2003a). On the one hand, openness on the export side is conducive to innovation to the extent that export-oriented production has to maintain competitiveness on world markets. On the import side, a high import penetration within

[2] Previous studies mostly referred to a three-digit SITC classification, which does not fully allow a complete breakdown of ICT products into final goods and intermediate parts and components.

the same industry is found to have positive spillovers on productivity catching-up. Overall, there is evidence of positive intra-industry spillovers of specialization in high-tech industries.

A second direction of research includes theoretical and empirical studies focussing on the hypothesis that technology catching-up is not independent from trade specialization. Stehrer and Wörz (2003b) recently tackled this issue in an empirical study exploring the hypothesis that the long-term position of a country may depend on its initial pattern of production specialization. The reason for this is that technology spillovers may occur mainly or at least are assumed to be stronger within one industry than across industries, due to learning processes and intra-industry linkages.[3] They find that the experience of East Asia would represent a case of countries starting off at the lower end of high-tech industries (i.e. producing less sophisticated consumer goods or assembling high-tech imported inputs) and then starting manufacturing high-tech intermediate goods.

A third direction is theoretical and empirical research suggesting that trade in intermediate goods is an important channel of the transmission of technology (Coe and Helpman, 1995; Coe, Helpman and Hoffmaister, 1995; Keller, 2001). A country's productivity depends not only on domestic R&D capital, but also on foreign R&D capital embedded in imported goods. The benefits from foreign R&D can be both direct and indirect. Direct benefits consist of learning about new technologies and materials, production processes, or organizational methods. Indirect benefits emanate from imports of goods and services that have been developed by trade partners. Therefore, the more open an economy is on the import side of high-tech industries, the more it should benefit from international spillovers on domestic productivity. Coe and Helpman (1995) found that foreign R&D capital stocks have stronger effects on domestic productivity the larger the share of domestic imports in GDP, and for smaller economies they are at least as important as domestic R&D capital stock. Hence, for emerging economies, imports of components for assembly may become the easiest way to acquire advanced technology and benefit from technological spillovers, which allows for an increase in total factor productivity.

In the case of China, there is some evidence that this might have actually happened during the 1990s. In particular, Cheung and Lin (2004), using provincial data for 1995-2000, show that there have been spillover effects of foreign direct investment on innovation activity via several channels, such as reverse engineering, skilled-labour turnover from foreign-investment-related firms to local firms, demonstration effects[4] and supplier-customer relationships[5]. Moreover, Lin and Wang (2003) find evidence of a positive effect of foreign direct investment on total factor productivity for a cross-sectional sample of Chinese industrial sectors in 1995.

In this paper, we explore the evolution of China's specialization in the ICT industry. Our aim is to assess whether processing and assembly trade have paved the way for higher forms of manufacturing exports, i.e. more skill- and technology-intensive production. The next section describes production fragmentation in ICT sectors and the position of China on world markets.

[3] This idea generalizes Krugman's notion of a ladder of countries and goods (Krugman, 1994).

[4] By their mere presence in the domestic market, foreign products/technologies can inspire and stimulate local innovators to develop new products and processes.

[5] Spillovers may take place vertically from foreign firms to their local suppliers by means of technological know-how transfer, staff training and so on.

3. Production fragmentation in the ICT industry

In the last decade, international fragmentation of production has been the focus of a growing economic literature.[6] The idea that production occurs internationally has been included in various models of international trade (Deardorff, 2001a, 2001b). More recently, models of foreign outsourcing have formalized firms' decisions to delocalize parts of their production activities abroad (Grossman and Helpman, 2002; Antràs and Helpman, 2003). Various issues associated with international fragmentation of production have been investigated (Arndt and Kierzkowski, 2001).

The phenomenon of international fragmentation of production has led to changes in the structure of international trade and in countries' specialization patterns. This splitting-up of the value chain allows for a more in-depth specialization: different stages of production correspond to different production functions so that a country may have a comparative advantage in one stage of production and comparative disadvantages in other stages. If comparative advantages can be found only in some stages of production, whereas others are disadvantaged, this is referred to as 'vertical' specialization. In the presence of vertical specialization, the analysis of trade patterns requires data at a sufficiently high level of disaggregation so as to be able to distinguish between final and intermediate goods. At least for ICT sectors, this is not fully feasible with less than a 5-digit level of disaggregation.

Empirical studies that have analysed trade patterns in the presence of the fragmentation have focussed mainly on major industrialized countries (Fontagné, Freudenberg, Ünal-Kesenci, 1996), Eastern European countries (Freudenberg and Lemoine, 1999) and East Asian countries (Ng and Yeats, 1999). These studies have highlighted the importance of intermediate goods and the influence of geographic proximity on production fragmentation among countries. They have also provided evidence of important cases of vertical division of labour and of 'switches' in comparative advantages along production processes.

The ICT industry is one of the most globally dispersed activities in the manufacturing sector. At the origin of this production fragmentation is a MAive international delocalization by leading multinational manufacturers, mainly based in the United States, in Japan and in some European countries (see Amighini, 2005 for a study of the evolution of telecom production through international production networks). This section analyses production fragmentation in the ICT industry over the last decade based on SITC trade data at five-digit level of disaggregation.

ICT production has been increasingly dispersed across countries over the last decade, as indicated by the high and growing exports of ICT parts and components during the 1990s (Table 1). ICT parts and components considerably increased both in export value and as a share of total ICT exports. As a result, in 2003 they accounted for the vast majority of total trade in ICT products: 93 per cent for Office machines, 73 per

[6] Although the term 'fragmentation' originated with Jones and Kierzkowski (1990), this phenomenon had already been identified by Dixit and Grossman (1982) and Bhagwati (1984), under the respective notions of multistage production and splintering. There are many other terms for the same phenomenon. The most frequent in the literature are: delocalisation (Leamer (1996), intra-product specialisation (Arndt, 1997), disintegration (Feenstra, 1998), global production sharing (Yeats, 1998), outsourcing (Feenstra, 1998), slicing up the value chain (Krugman, 1996), and vertical specialisation (Hummels et al., 1998). See Deardorff's Glossary of International Economics, available at http://www-personal.umich.edu/~alandear/glossary/

cent for Semiconductors, 41 per cent for IT products and 28 per cent for Telecom equipment.

Table 1 Exports of ICT products, 1992 and 2003 (bln $)

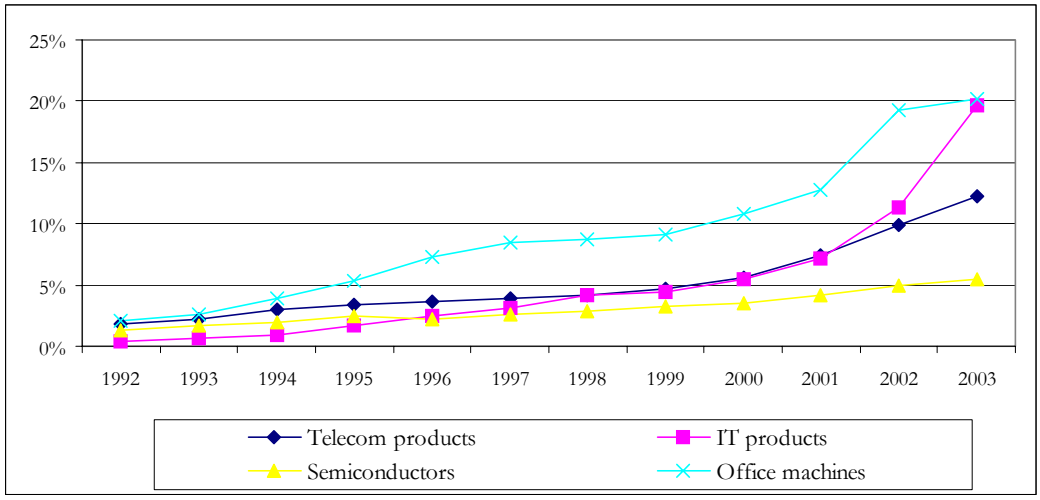
	1992	2003
Office machines (incl. parts)	74	186
Parts thereof (% of total)	62 (83%)	173 (93%)
IT products (incl. parts)	134	380
Parts thereof (% of total)	52 (39%)	157 (41%)
Telecom products (incl. parts)	104	359
Parts thereof (% of total)	32 (31%)	99 (28%)
Semiconductors (incl. parts)	123	431
Parts thereof (% of total)	81 (66%)	313 (73%)

Source: elaborated on UNSD Comtrade Database

Within this increasing fragmentation, China largely improved its market shares. During the 1990s, China became the largest world exporter of Office machines (18 per cent of world exports), of IT products (18 per cent of world exports) and of Telecom products (11 per cent of world exports) (Figures 1 and 2). China also substantially increased its market share in Semiconductors (up to almost 5 per cent of world exports in 2003).

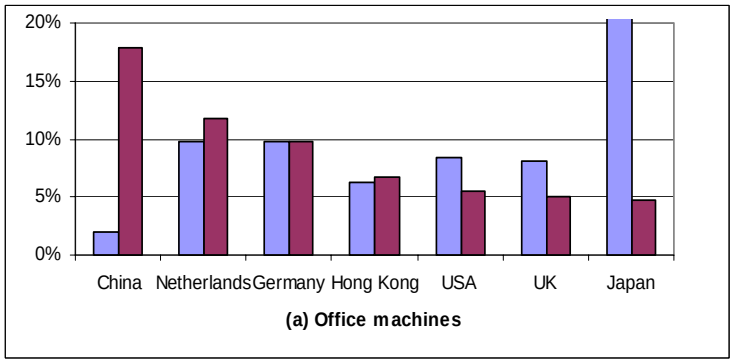
Being a leading exporter of final goods in a highly fragmented market does not necessarily imply domestic specialization in the production of those goods. This is in fact the case of China, where the high import content of ICT exports (Figure 3) suggests that the country is – at least at aggregate level – specialized in the labour-intensive final stages of production rather than in high-technology stages of ICT production (i.e. the manufacturing of parts and components where technology is actually embedded).

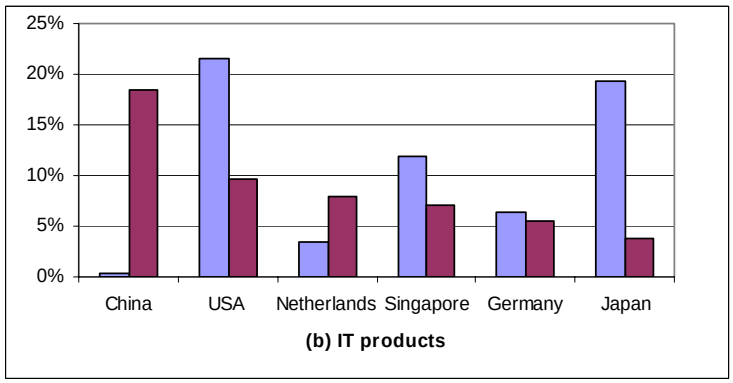
Figure 1 China's market shares of ICT products, 1992-2003 (% of world exports)

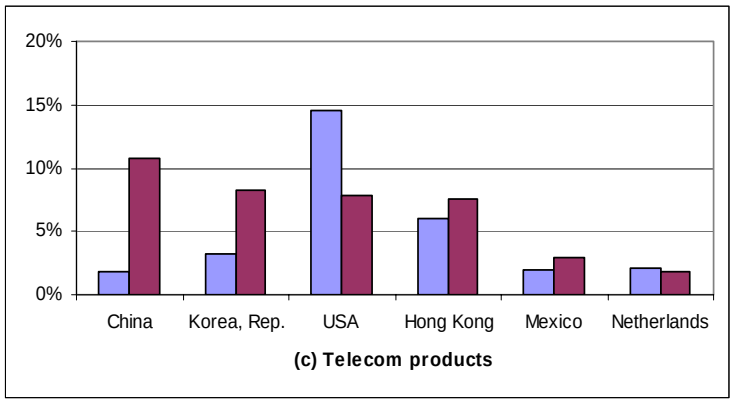


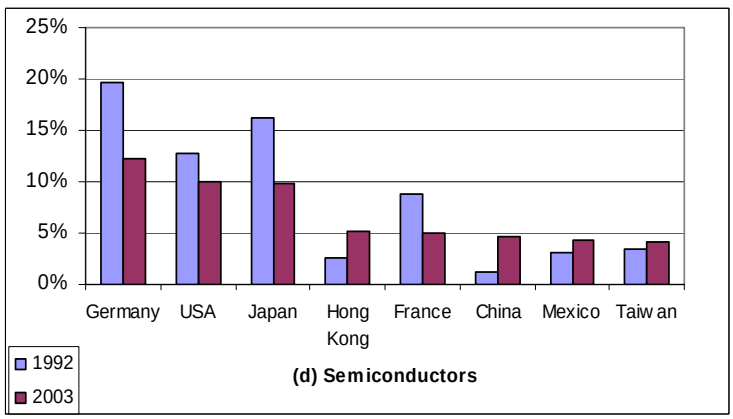
Source: elaborated on UNSD Comtrade Database

Figure 2 Top exporters of ICT products, 1992 and 2003 (% market share)



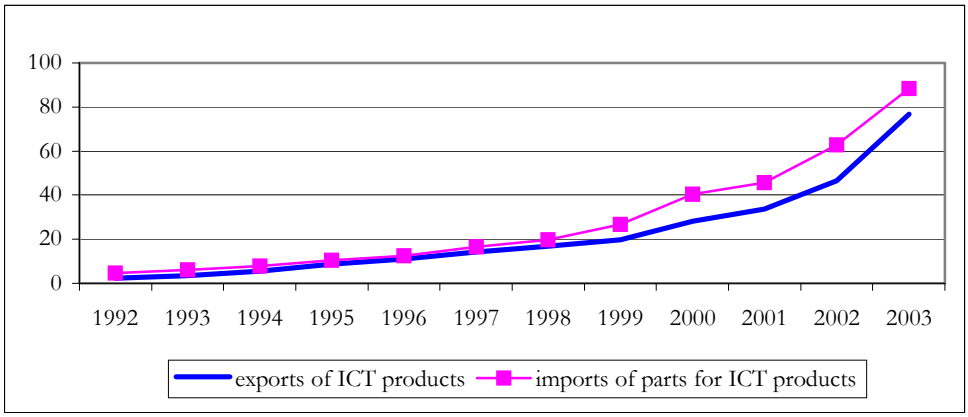






Source: elaborated on UNSD Comtrade Database

Figure 3 Trade of ICT products and parts, 1992-2003 (bln $)



Source: elaborated on UNSD Comtrade Database

However, during the 1990s, China upgraded from mere assembly of imported inputs to the direct manufacturing of ICT products. China has indeed increased its market shares in ICT parts and components. Now it is the second largest exporter of parts of Office machines (10.7 per cent of world exports), of parts of IT products (11 per cent), and as the third largest exporter of Telecom products (12.6 per cent). Parts and components now make up a major part of ICT exports for China: 40 per cent for Office machines, more than 44 per cent for Telecom products, over 63 per cent for IT products and over 80 per cent for Semiconductors. The next section analyses China's specialization profile in order to see to what extent this increasing participation in ICT production has changed the country's comparative advantages (CA).

4. Evolution of China's Specialisation Profile in the 1990s

After an overview of Chinese specialisation in the 1990s in Section 4.1, Section 4.2 analyses Chinese CA in the ICT industry at product level.

4.1. International specialisation pattern.

This section provides an overview of the pattern of international specialization of China by sector over the 1990s. We follow a sector classification according to factor intensity: manufacturing is distinguished into human capital/skill-intensive sectors, unskilled labour-intensive sectors and technology-intensive sectors.[7]

Not surprisingly, China shows up as being specialized in unskilled labour-intensive sectors, both in 1991 and in 2001 (Table 2). A slight reduction of specialization occurred over the decade, resulting mainly from a decrease in intensity of CA (in textile and clothing and in plastic goods, toys and office equipment), but not from a decrease in the scope of specialization (i.e. the number of sectors with a CA).

As regards skill- and technology-intensive sectors, China has still a comparative disadvantage in the aggregate, but shows some CAs in selected sub-sectors. Within skill-

[7] This classification was first adopted by Garnaut and Anderson (1980), and then by Krause (1982) and Park and Park (1991). Chiarlone and Helg (2002) applied this classification to East Asian economies compared to Italy.

intensive industries, China has been specialized in electric appliances and audio-visual equipment since the 1980s and still maintains a strong CA in those sectors. Within technology-intensive sectors, China had no CA up to the early 1990s, but during the decade developed a specialization in electronic machinery, IT, telecom and office equipment, and electric goods.

This expansion of trade in the electronics and especially in the ICT sectors results from increasing inward foreign direct investment in those sectors and from growing involvement of the country in global production networks as a production base for leading manufacturers.

Table 2 Balassa index of revealed comparative advantages for China, 1991 and 2001

	1991	2001
Leather Products	0.6	0.6
Cork and Wood Products	0.9	1.1
Textiles Clothing and Footwear	**4.1**	**2.7**
Non Metallic Manufactures	**5.4**	**5.4**
Ships	0.6	0.9
Furniture and Plumbing Equipments	0.1	0.6
Miscellaneous	**1.0**	**2.5**
Leather Products	**5.9**	**4.3**
Unskilled labour-intensive sectors	**3.4**	**2.7**
Dyeing, tanning and colouring materials; Essential Oils for perfumes and cleansing	0.2	0.3
Rubber and Paper Products	0.1	0.3
Metallic & Non Metallic Manufactures	0.5	0.7
Televisions, Radio & Other Sound related receivers, reproducers & recorders	**2.6**	**2.5**
Household Equipments	**2.3**	**2.9**
Road and Railways Vehicles	0.1	0.1
Miscellaneous	0.8	0.9
Skill-intensive sectors	0.5	0.5
Chemicals, Medicinal and Pharmaceutical Products, Fertilisers and Plastics	0.4	0.3
Power Generating Machines	0.5	0.2
Other Non Electrical Machinery	0.2	0.3
Office Mach and Telecom Equipment	0.2	0.4
Electrical Machineries and apparatus	0.3	**1.1**
Aircraft	0.4	**1.2**
Professional Goods	0.0	0.0
Chemicals, Medicinal and Pharmaceutical Products, Fertilisers and Plastics	0.3	0.7
Technology-intensive sectors	0.3	0.7

Source: Amighini and Chiarlone (2005)

In order to get a better understanding of the evolution of the Chinese pattern of trade in the ICT industry, the next section analyses CAs at a five-digit level of disaggregation, for each of the four sub-sectors of the ICT industry: Office machines, IT products, Telecom products and Semiconductors. In each sub-sectors, we will distinguish between final and intermediate products.

4.2. Specialization profile in ICT sectors.

This section analyses the pattern of international specialization of China in the ICT industry, by computing the revealed comparative advantage (RCA) index at product

level. [8] This allows assessing if a country is specialized in final or intermediate goods. Distinguishing between final and intermediate goods is crucial to evaluate the level of industrial development of a sector, for the following reasons. RCAs on exports of final goods show if a country concentrates in those goods a share of its exports greater than the world does. However, they do not necessarily imply that the country is mastering the entire production process in a sector. Instead, if the import content of exports is high, they might as well show a specialization in assembly of imported inputs. Therefore, even high RCAs on exports in final high tech goods do not provide any information on the level of industrial development of a country in that sector. On the contrary, RCAs on exports of intermediate inputs in skill- or technology-intensive sectors show a specialization in the manufacturing of such products, which is per se a more technologically advanced and higher value added activity than assembly.

With this distinction in mind, we can read RCAs reported in Table 5. RCAs show that China has developed several new comparative advantages in several products over the 1990s, both in final and intermediate products in all the four sub-sectors (Table 3 in Appendix). The highest number of RCA can be found in Telecom products and parts thereof (where the country now has a comparative advantage in all intermediate products). China also developed a specialization in parts for IT products, for Office machines and for Semiconductors. Overall, the country has new RCAs in more than 30 per cent of ICT intermediate goods, almost all of them developed during the 1990s. This indicates a switch from being mainly an assembler to being also a producer of skill- and technology-intensive products.

We further elaborate on this evidence by computing another index of international specialization: the net trade index (NET) [9], also known as normalised trade balance. NETs computed at product level show the net trade position of a country and therefore inform whether the country is a pure or net exporter or importer of each product. By so doing, the NET index is a more accurate measure of CA, because it takes into account imports as well as exports. A positive NET indicates that the country is a net exporter of a good. A higher NET corresponds to a higher CA. In this way, the

[8] The revealed comparative advantage (RCA) index by Balassa (1965) is the most commonly used measure of international specialization. It says whether a country concentrate in a particular sector (or product) a share of its exports greater than the world does and takes such a concentration as an evidence of comparative advantages. The index varies between zero and infinite. Values bigger than one mean that the country has a comparative advantage. The opposite is true for values lower than one. It is calculated as the share of a country in world trade of product j divided by its share of world merchandise trade:

$$\textbf{RCA:}\quad \frac{X_{j}^{k}}{X_{j}^{w}} \Bigg/ \frac{\sum_{j} X_{j}^{k}}{\sum_{j} X_{j}^{w}} \quad \text{where k = country; j = product; w = world.}$$

[9] The net trade index (NET) is an 'on average' indication of 'true' comparative advantage (Deardorff, 1980; Balance et al., 1987). The index varies between –1 and 1: 1 indicates pure exports and the highest comparative advantage; -1 indicates pure imports and the highest disadvantage; 0 indicates balanced trade, or the maximal intra-industry trade. It is computed as net exports of product k from country i divided by the sum of trade flows of product k by country i:

$$\textbf{NET:}\quad \frac{X_{ik}^{t} - M_{ik}^{t}}{X_{ik}^{t} + M_{ik}^{t}} \quad \text{where i = country; k = product}$$

NET allows singling out the cases where the country has a CA but also has a high import dependence of the same products (and therefore a relatively low NET).

The analysis of NET indices for each of the four sub-sectors considered shows that China has considerably improved its specialization in *final* ICT equipment, and also recorded a considerable increase in its trade balance of *intermediate* ICT goods. This confirms the results from RCA analysis that China developed some CAs in skill- and technology-intensive products.

As regards final ICT products, the country has become a strong *net exporter* for several goods (Table 4):

- Office machines: the NET index has slightly increased from 1991 to 2001, and confirms that China is becoming a stronger net exporter of these products, and in several cases is almost a pure exporter (NET → 1). In many of these products China was already a strong net exporter in 1991, but in some of them it dramatically reversed from being almost a pure net importer to being a strong net exporter (e.g. photo-copying and addressing machines).
- IT products: China has considerably improved its performance from net imports in 1991 to strong net exports in 2001. The NET index changed from negative to positive in almost all product lines and in some of them the country is now a strong net exporter.
- Telecom products: China considerably improved, by reversing its net trade position from being a net importer in 1992 to a positive balance in 2001.
- Semiconductors: unlike the previous three sub-sectors, China's trade position in Semiconductors has not changed during the 1990s; the country is still a strong net importer of semiconductors, electrical circuits and parts and components thereof.

A different scenario emerges for parts and components of all ICT products: NETs show that China continues to be mainly a *net importer*, despite an increase in several NET indices over the 1990s. Now the majority of NET indices are around 0, showing a dominance of intra-industry trade in these sectors. Again, this confirms that China's high dependence on imports of intermediate goods has been decreasing and that the country is now manufacturing a higher share of intermediate skill- and technology-intensive goods for exports.

This diversification of China's ICT exports from a dominance of assembly trade towards more technologically advanced production is likely to be the result of a process of industrial learning fuelled by intra-industry spillovers. An interesting point to notice here is that the initial specialization in processing and assembly trade was achieved through a policy-induced change of comparative advantages.

Since the beginning of the 1980s, China's trade policy has been progressively liberalized but its trade regime has remained dualistic, as Chinese authorities used different policy instruments to promote exports (Lemoine, 2000). The first instrument of trade policy was the reduction in tariff and non-tariff barriers. Since 1992 China has substantially lowered its tariff rates, which fell from 42.9 per cent in 1992 to 17.5 per cent in 1997, on average. Quota and licenses were also reduced (World Bank, 1997). The second instrument was duty exemptions granted to selected categories of imports,

which aimed at promoting export-oriented and at stimulating the inflows of capital and technology through FDI. Intermediate imported products to be used in the production of exports were the most important category benefiting from tariff exemptions. China's trade policy, which has granted tariff exemptions to imports used for processing and re-exports, has proved very successful in creating export-oriented industries.

As processing trade took an increasingly dominant part in total trade, its structural changes have strongly influenced China's overall trade pattern towards a specialization in processing and assembly, i.e. in the labour intensive stages of production. During the 1990s, then, China managed to catch-up in high-tech sectors by developing new CAs in the skill- and technology- intensive stages of production. Although this upgrading is not the effect of any policy measure, the initial policy-induced specialization in the lower end of the ICT industry has paved the way for intra-industry catching-up and therefore proved positive from a long-term development point of view.

5. Concluding remarks

All industries generate and/or exploit new technology and knowledge to some extent, but some are more technologically- and/or knowledge-intensive than others. The impressive growth of Chinese trade over the 1990s can be largely attributed to trade in high-tech manufactures.

The possibility of a country to take full advantage from international trade and direct investment depends on the capacity to rapidly absorb technical progress. In particular, a country's participation in international trade of technology-intensive products and its openness to foreign direct investment in high-tech sectors will be conducive to technological learning provided that other inputs into the innovation process are in place, such as human resources, investment in innovation and R&D activities and policies. Therefore, the potential for industrial catching-up through are strongly associated to the number of scientists, engineers and researchers available in the country, and more in general to its education system.

This paper has assessed the extent to which there has been industrial catching-up in ICT sectors – Telecom products, IT products, Semiconductors and Office machines - that were mostly involved in the so-called processing trade, i.e. the processing of imported inputs into final products destined to foreign markets. The results show that an evolution occurred in the country's specialisation structure from mere assembly of imported inputs for export to the manufacturing of a wider range of technology-intensive products, which supports the notion of industrial upgrading. In particular, the dramatic surge in exports of high-technology goods has been accompanied over time by a switch from China being a net importer to it being a net exporter of parts and components for ICT products (which suggests that the core of ICT production has progressively moved to China through foreign direct investment by leading manufacturers). Indeed, China became the world's largest recipient of FDI in 2002, with almost USD 50 billion of inflows. In particular, it is a mostly preferred location for outsourcing of ICT production. This has favoured knowledge diffusion and technological learning (for a case-study of the telecommunications industry in China, see Mu and Lee, 2005). More recently has started acquiring FDI in ICT sectors, i.e. with the acquisition of the PC section of IBM by Chinese Lenovo.

Behind this catching-up through processing trade, there has also undoubtedly been considerable investment in human capital and R&D activities. As regards human

capital, the absolute number of enrolments in, and graduates from tertiary education in China match the numbers in the United States and the EU. Moreover, a substantial number of Chinese students enroll in OECD countries, at least half of them in the United States (Schaaper, 2004, p. 3). As regards R&D, there has been a huge expansion in the number of researchers in China since 1999. China counts now more researchers than Japan, and is on its way to potentially overtake the EU as well (Schaaper, 2004, p. 3). The amount of money spent in R&D increased even faster than the researchers base. R&D intensity has been rising rapidly, and China has reached its target of spending 1.5 per cent of GDP on R&D in 2005.

This supports the hypothesis that selective policy measures, such as preferential tariff treatment to assembling and processing activities introduced in China, can be welfare improving as formalized by Redding (1999). Those measures encouraged an increasing involvement of the country in production fragmentation, to the extent that final stages of production in Asian mature economies have tended to migrate to China, enhancing its export capacities and regional integration. This vertical specialization enabled China to rapidly diversify its exports of consumption goods and to switch its comparative advantages along production processes from unskilled labour-intensive assembly to more advanced processing activities. This is consistent with many studies highlighting that China's export performance since the mid-eighties was closely connected with the reorganization of production within Asia (Naughton, 1997; Lemoine, 1999 and 2000; Sung, 2000; Parker and Lee, 2001).

Therefore, a pattern of specialization initially dominated by processing trade could be potentially favourable to a country's long-term development, to the extent that entering at the lower end of high-tech sectors is promotive of catching up in more sophisticated technology-intensive production. From a development point of view, the Chinese experience suggests to further investigate the conditions and paths of technological learning in advanced sectors. This would be mostly useful for other developing countries with a current strong specialization in processing and assembly trade, such as Mexico.

References

Amighini A., Chiarlone S. (2005), 'Rischi dell'integrazione commerciale cinese per il moello di specializzazione internazionale dell'Italia', *Rivista di Politica Economica* (forthcoming).

Amighini, A. (2005), 'From Global to Regional International Production Networks in the Telecom Sector: Implications for Industrial Upgrading in East Asia', *European Journal of East Asian Studies*, **4.1**, 115-142

Antràs P., Helpman E. (2003), 'Global Sourcing', *NBER Working Paper No. 10082*.

Arndt S. (1997), 'Globalisation and the Open Economy', *North-American Journal of Economics and Finance*, **8** , 71-79

Arndt S., Kierzkowski H. (eds) (2001), *Fragmentation. New Production Patterns in the World Economy*, Oxford University Press, Oxford

Balassa B. (1965), 'Trade Liberalization and Revealed Comparative Advantage', *Manchester School of Economic and Social Studies*, **39**, 99-117

Bhagwati J. N. (1984) 'Splintering and Disembodiment of Services and Developing Nations', *The World Economy*, **7**, 133-143

Cheung, K.-y., Lin, P. (2004), 'Spillover effects of FDI on innovation in China: Evidence from the provincial data', *China Economic Review*, **15**, 25-44

Chiarlone S., Helg R. (2002), "Il modello di specializzazione internazionale italiano e le economie emergenti dell'Estremo Oriente" in Galli G. and Paganetto L. (eds), *La competitività dell'Italia*: *Ricerca del Centro Studi di Confindustria,* Vol. 2: Le imprese, Il Sole 24 Ore, Milano.

Coe D. T., Helpman E. (1995), 'International R&D Spillovers', *European Economic Review*, **39**, 859-887

Coe D. T., Helpman E., Hoffmaister A. W. (1995), 'North-South R&D Spillovers', *NBER Working Paper No.5048*.

Deardorff A. (1980), 'The General Validity of the Law of Comparative Advantage', *Journal of Political Economy*, **88**, 941-957

Deardorff A. (2001a), 'Fragmentation in Simple Trade Models', *North American Journal of Economics and Finance*, **12**, 121-137

Deardorff A. (2001b), 'Fragmentation across Cones', in Arndt S. W. and Kierzkowski H. (eds), *Fragmentation: New Production Patterns in the World Economy*, Oxford University Press, Oxford.

Dixit A. K., Grossman G. M. (1982), 'Trade and Protection with Multistage Production', *Review of Economic Studies*, **59**, 583-594

Dowling M., Cheang C. T. (2000), 'Shifting Comparative Advantage in Asia: New Test of the "Flying Geese" Model', *Journal of Asian Economics*, **11**, 443-463

Feenstra R. C. (1998), 'Integration of Trade and Disintegration of Production in the Global Economy', *Journal of Economic Perspectives*, **14**, 31-50

Fontagné L., Freudenberg M., Ünal-Kesenci D. (1996), 'Statistical Analysis of EC Trade in Intermediate Products', *External Trade Series – Studies and Research, 6D, Eurostat.*

Freudenberg M., Lemoine F. (1999), 'Central and Eastern European Countries in the International Division of Labour in Europe', *CEPII Working Pape No.05*.

Garnaut R. G., Anderson K. (1980), 'Asean export specialization and the evolution of comparative advantage in the Western Pacific region', in Garnaut R. G. (ed.), *Asean in a changing Pacific and world economy*, Australian National University Press, Canberra.

Grossman G. M., Helpman E. (1991), *Innovation and Growth in the Global Economy*, MIT Press, Cambridge, MA.

Grossman G. M., Helpman E. (1994), 'Endogenous Innovation in the Theory of Growth' *Journal of Economic Perspectives*, **8**, 23-44

Grossman G. M., Helpman E. (2001), 'Outsourcing in the Global Economy', mimeo.

Helpman E. (1992), 'Endogenous macroeconomic growth theory', *European Economic Review*, **36**, 237-267

Hummels D., Rapoport D., Yi K.-M. (1998), 'Vertical Specialization and the Changing Nature of World Trade', *FRBNY Economic Policy Review*, June, 79-9

Jones R. W., Kierzkowski H. (1990), 'The Role of Services in Production and International Trade: A Theoretical Framework', in Jones R. W. and Krueger A. O. (eds), *The Political Economy of International Trade: Essays in Honor of Robert E. Baldwin*, Blackwell, Cambridge, MA.

Keller W. (2001), 'The Geography and Channels of Diffusion at the World's Technology Frontier', *NBER Working Paper No. 8150*.

Krause L. B. (1982), *U.S. Economic Plocy toward the Association of South East Asian Nations: Meeting the Japanese Challenge*, Brooking Institutions Press, Washington D.C.

Krugman P. (1994), 'A 'Technology Gap' Model of International Trade', in Krugman P. (ed.), *Rethinking International Trade*, MIT Press, Cambridge, MA.

Krugman P. (1996), 'Does Third World Growth Hurt First World Prosperity?' *Harvard Business Review*, **72**, 113-121

Lardy N. R. (2002), *Integrating China into the World Economy*, Brookings Institution Press, Washington, D.C.

Leamer E. E. (1996), 'The Effects of Trade in Services, Technology Transfer and Delocalisation on Local and Global Income Inequality', *Asia-Pacific Economic Review*, **2**, 44-60

Lemoine F., Ünal-Kesenci D. (2002), 'China in the International Segmentation of Production Processes', *CEPII Working Paper No. 02.*

Lemoine F. (1999), 'Les délocalisations au coeur de l'expansion du commerce extérieur chinois', *Economie et statistique*, **326-327**, 53-70

Lemoine F. (2000), 'FDI and Opening Up of China's Economy', *CEPII Working Paper No.11.*

Lin, X., Wang, C. (2003), 'Does foreign direct investment facilitate technological progress? Evidence from Chinese industries', *Research Policy*, **32**, 945-953

Mu, Q., Lee, K. (2005), 'Knowledge diffusion, market segmentation and technological catch-up: The case of the telecommunication industry in China', *Research Policy*, forthcoming.

Naughton B. (1997), *The China Circle: Economic and Technology in the PRC, Taiwan and Hong Kong*, Brookings Institution Press, Washington, D.C..

Ng F., Yeats A. (1999), 'Production Sharing in East Asia: Who does What, for Whom and Why?', World Bank, *Policy Research Working Paper No. 2197.*

Park Y.C., Park W.A. (1991), 'Changing Japanese Trade Patterns and East Asian NICsc', in Krugman P. (Ed.), *US and Japan: Trade and Investment in the 1990s*, University of Chicago Press, Chicago

Parker S., Lee S. (2001), 'Did East-Asian Developing Economies Lose Export Competitiveness in the Pre-Crisis 1990s? Assessing the East-Asian Export Performance from 1980 to 1996', *Asian Development Bank Institute*

Redding S. (1999), 'Dynamic Comparative Advantage and the Welfare Effects of Trade', *Oxford Economic Papers*, **51**, 15-39

Schaaper, M. (2004), 'An emerging knowledge-based economy in China? Indicators from OECD databases', *STI Working Paper No.4.*

Stehrer R., Worz J. (2003a), 'Industrial Diversity, Trade Patterns and Productivity Convergence', *WIIW Working Paper No. 23.*

Stehrer R., Worz J. (2003b), 'Technological Convergence and Trade Patterns', *Weltwirtschaftliches Archiv*, **139**, 1-28

Sung Y.-W. (2000), 'Costs and Benefits of Exports-oriented Foreign Investment: The Case of China', *Asian Economic Journal*, **14**, 55-70

Tung A.-C. (2003), 'Beyond Flying Geese: The Expansion of East Asian Electronics Trade', *German Economic Review*, **4**, 35-51

World Bank (1997), *China Engaged: Integration with the Global Economy*,.The World Bank,. Washington, D.C.

Yeats A. J. (1998), 'Just How Big Is Global Production Sharing?' *Policy Research Working Paper No. 1871.*

Appendix tables

Table 3 Chinese RCAs for the ICT industry, 1991 and 2001

Office machines	1991	2001
75113 Automatic typewriters; word processing machines	0.07	0.17
75115 Other electric typewriters, weighing < 12kg	0.02	0.23
75116 Other electric typewriters	0.00	0.10
75118 Non-electric typewriters, weighing < 12 kg	0.72	0.88
75119 Other non-electric typewriters	0.00	0.10
75121 Electronic without external source of power	**7.46**	**6.70**
75122 Other calculating machines	**5.75**	**2.43**
75123 Accounting machines	0.00	0.27
75124 Cash registers, incorporating a calculating device	0.02	**1.92**
75128 Postage-franking & similar mach., with calc. device	0.39	0.54
75131 Electrostatic photo-copy. apparatus, direct process	0.00	**1.08**
75132 Electrostatic photo-copy. apparatus, indirect proc.	0.02	**2.11**
75133 Non-electrostatic photo-copying apparatus, optical	0.01	0.13
75134 Non-electrostatic photo-copying apparatus, contact	0.00	0.05
75135 Thermo-copying apparatus	0.00	0.29
75191 Duplicating machines	0.00	0.08
75192 Addressing machines, address plate embossing m.	0.00	0.11
75193 Machines for sorting, folding, opening, etc., mail	0.07	0.06
75199 Office machines, n.e.s.	0.80	**2.05**
Parts thereof	1991	2001
7591 Parts, accessories of the apparatus of heading 7513	0.02	**1.25**
75991 Parts, accessori. of the machines of sub-group 7511	0.09	0.21
75993 Parts, accessori. of the machines of sub-group 7519	0.10	0.58
75995 Parts, accessori. of the machines of sub-group 7512	0.15	**2.04**
Telecom products	1991	2001
76411 Telephone sets	**6.09**	**7.07**
76413 Teleprinters	0.05	0.33
76415 Telephonic or telegraphic switching apparatus	0.01	0.13
76417 Other apparatus for carrier-current liner systems	0.06	0.00
76419 Other telephonic or telegraphic apparatus	0.30	**1.15**
76421 Microphones & stands therefor	**1.36**	**2.23**
76422 Loudspeakers, mounted in their enclosures	0.37	**4.91**
76423 Loudspeakers, not mounted in their enclosures	0.99	**4.60**
76424 Headphones, earphones & combined microphone/speaker	**5.02**	**10.05**
76425 Audio-frequence electric amplifiers	0.80	**1.41**
76426 Electric sound amplifier sets	0.45	**1.89**
76431 Transmission apparatus	0.30	**1.00**
7526 Input or output units, whether or not with storage	0.23	**3.56**
7527 Storage units, with the rest of a system or not	0.01	**1.54**
7529 Data processing equipment, n.e.s.	0.24	0.93
Parts thereof	1991	2001
75997 Parts, accessories of the machines of group 752	0.14	**2.06**
Semiconductors	1991	2001
7722 Printed circuits	0.11	**1.20**
77231 Fixed carbon resistors, composition or film types	0.09	0.29
77232 Other fixed resistors	0.05	0.79
77233 Wirewound variable resistors	0.07	0.96
77235 Other variable resistors	0.04	0.90
77238 Parts for the electrical resistors of heading 7723	0.00	0.28
77241 Fuses, voltage > 1000 volts	0.08	0.09
77242 Automatic circuit breakers for a voltage < 72, 5 kv	0.05	0.04
77243 Other automatic circuit breakers, voltage > 1000 v	0.08	0.06
77244 Isolating switches, make-and-break switches, >1000 v	0.06	0.08
77245 Lightning arresters, voltage limiters, surge suppre.	0.26	0.90
77249 Other apparatus for electrical circuits>1000 volts	0.34	0.32
77251 Fuses, voltage < 1000 volts	0.26	0.62
77252 Automatic circuit breakers, voltage < 1000 volts	0.04	0.65
77253 Other apparatus for protecting electrical circuits	0.87	**4.18**
77254 Relays, voltage < 1000 volts	0.22	0.86
77255 Other switches, voltage < 1000 volts	0.56	0.83
77257 Lampholders, voltage < 1000 volts	**2.20**	**1.56**
77258 Plugs & sockets, voltage < 1000 volts	0.85	**2.18**
77259 Other apparatus for electrical circuits<1000 volts	0.31	**0.98**
77261 Boards, panels for electric distribution<1000 volts	0.40	0.83
77262 Boards, panels for electric distribution>1000 volts	0.01	0.06
77281 Bases for the goods of heading 7726, not equipped	0.01	0.14
77282 Other parts for apparatus of 7724, 7725 & 7726	0.07	0.27
Parts thereof	1991	2001
77611 Colour television picture tubes, cathode ray	0.30	0.69
77612 Monochrome television picture tubes, cathode ray	0.06	0.30
77621 Television camera tubes; image converters, intensi.	0.16	0.19
77623 Other cathode-ray tubes	0.01	0.19
77625 Microwaves tubes (excluding grid-controlled tubes)	0.04	0.02
77627 Other valves & tubes	0.58	0.10
77629 Parts of the tubes, valves of sub-groups 7761, 7762	0.05	**1.22**

76432 Transmission apparatus with reception apparatus	**2.38**	**4.27**	77631 Diodes, not photosensiti. nor light emitting diodes	0.08	**1.01**
76481 Reception appar. for radio-teleph., -telegr., n.e.s.	**1.36**	0.99	77632 Transistors, dissipation rate < 1 w	0.18	**1.24**
76482 Television cameras	0.00	0.19	77633 Transistors, dissipation rate > 1 w	0.01	0.77
76483 Radar, radio-navigat. aid, -remote control apparatus	0.06	0.42	77635 Thyristors, diacs & triacs	0.04	0.53
Parts thereof	1991	2001	77637 Photosensitive semi-conductor devices; light emitt.	0.23	**2.28**
76491 Parts & accessories for apparatus of heading 7641	0.12	**1.68**	77639 Other semi-conductor devices	0.33	0.98
76492 Parts & accessories for apparatus of heading 7642	0.44	**2.03**	77641 Digital monolithic integrated circuits	0.00	0.35
76493 Parts & accessories of 761, 762, 7643, 7648	0.39	**2.11**	77643 Non-digital monolithiques integrated circuits	0.00	0.29
76499 Parts & accessories for apparatus of group 763	**1.18**	**3.66**	77645 Hybrid integrated circuits	0.03	0.40
IT products	1991	2001	77649 Other electro. integrated circuits, microassemblies	0.02	0.33
7521 Analog or hybrid data processing machines	0.15	0.07	77681 Piezo-electric crystals, mounted	0.15	**3.38**
7522 Dig. autom. data proces. machines, cent. proc. unit	0.07	0.67	77688 Parts of the devices of 7763 & of item 77681	0.01	0.56
7523 Digital proces. units with: storage, input, output	0.09	0.48	77689 Parts of the articles of heading 7764	0.01	0.18

Source: elaborated on OECD data

Table 4 Chinese NETs for the ICT industry, 1991 and 2001

Office machines	1991	2001	7526 Input or output units, whether or not with storage	0.35	0.72
75113 Automatic typewriters; word processing machines	-0.13	-0.91	7527 Storage units, with the rest of a system or not	-0.29	0.27
75115 Other electric typewriters, weighing < 12kg	-0.85	0.26	7529 Data processing equipment, n.e.s.	-0.89	0.64
75116 Other electric typewriters	0.05	-	**Parts thereof**	1991	2001
75118 Non-electric typewriters, weighing < 12 kg	0.73	1.00	75997 Parts, accessories of the machines of group 752	0.00	0.09
75119 Other non-electric typewriters	0.07	-	**Semiconductors**	1991	2001
75121 Electronic without external source of power	0.96	0.92	7722 Printed circuits	-0.14	-0.12
75122 Other calculating machines	0.97	0.99	77231 Fixed carbon resistors, composition or film types	-0.28	-0.46
75123 Accounting machines	-0.74	-0.16	77232 Other fixed resistors	-0.69	-0.47
75124 Cash registers, incorporating a calculating device	-0.46	-0.09	77233 Wirewound variable resistors	-0.30	-0.52
75128 Postage-franking & similar mach., with calc. device	-0.93	-0.42	77235 Other variable resistors	-0.11	-0.20
75131 Electrostatic photo-copy. apparatus, direct process	0.03	-0.78	77238 Parts for the electrical resistors of heading 7723	-0.53	-0.70
75132 Electrostatic photo-copy. apparatus, indirect proc.	-0.60	0.91	77241 Fuses, voltage > 1000 volts	-0.88	-0.07
75133 Non-electrostatic photo-copying apparatus, optical	-0.99	-0.34	77242 Automatic circuit breakers for a voltage < 72, 5 kv	-0.80	-0.91
75134 Non-electrostatic photo-copying apparatus, contact	0.53	-0.97	77243 Other automatic circuit breakers, voltage > 1000 v	-0.94	-0.83
75135 Thermo-copying apparatus	-0.97	-0.59	77244 Isolating switches, make-and-break switches>1000v	-0.44	-0.85
75191 Duplicating machines	-0.89	-0.25	77245 Lightning arresters, voltage limiters, surge suppre.	-0.79	-0.69
75192 Addressing machines, address plate embossing m.	-1.00	0.72	77249 Other apparatus for electrical circuits>1000 volts	-0.99	-0.49
75193 Machines for sorting, folding, opening, etc., mail	-0.68	-0.85	77251 Fuses, voltage < 1000 volts	-0.13	-0.60
75199 Office machines, n.e.s.	0.14	0.07	77252 Automatic circuit breakers, voltage < 1000 volts	-0.66	0.04
Parts thereof	1991	2001	77253 Other apparatus for protecting electrical circuits	-0.27	-0.42
7591 Parts, accessories of the apparatus of heading 7513	-0.57	0.07	77254 Relays, voltage < 1000 volts	0.10	0.05
75991 Parts, accessori. of the machines of sub-group 7511	-0.70	-0.16	77255 Other switches, voltage < 1000 volts	0.02	-0.17

75993 Parts, accessori. of the machines of sub-group 7519	0.06	-0.28
75995 Parts, accessori. of the machines of sub-group 7512	-0.53	-0.06
Telecom products	1991	2001
76411 Telephone sets	0.86	0.97
76413 Teleprinters	-0.46	-0.97
76415 Telephonic or telegraphic switching apparatus	-0.97	0.43
76417 Other apparatus for carrier-current liner systems	-0.81	-
76419 Other telephonic or telegraphic apparatus	-0.84	0.68
76421 Microphones & stands therefor	0.04	0.00
76422 Loudspeakers, mounted in their enclosures	-0.02	0.87
76423 Loudspeakers, not mounted in their enclosures	0.48	0.60
76424 Headphones, earphones & combined microphone/speaker	0.73	0.65
76425 Audio-frequence electric amplifiers	-0.22	0.80
76426 Electric sound amplifier sets	-0.70	0.61
76431 Transmission apparatus	-0.89	-0.60
76432 Transmission apparatus with reception apparatus	-0.57	0.48
76481 Reception appar. for radio-teleph., -telegr., n.e.s.	-0.84	-0.30
76482 Television cameras	-0.95	0.03
76483 Radar, radio-navigat. aid, -remote control apparatus	-0.29	-0.03
Parts thereof	1991	2001
76491 Parts & accessories for apparatus of heading 7641	-0.85	-0.43
76492 Parts & accessories for apparatus of heading 7642	-0.43	0.05
76493 Parts & accessories of 761, 762, 7643, 7648	-0.33	-0.07
76499 Parts & accessories for apparatus of group 763	-0.27	0.10
IT products	1991	2001
7521 Analog or hybrid data processing machines	-0.57	-0.96
7522 Dig. autom. data proces. machines, cent. proc. unit	-0.85	0.26
7523 Digital proces. units with: storage, input, output	-0.76	0.08
77257 Lampholders, voltage < 1000 volts	0.80	0.57
77258 Plugs & sockets, voltage < 1000 volts	0.23	0.01
77259 Other apparatus for electrical circuits<1000 volts	-0.20	-0.37
77261 Boards, panels for electric distribution<1000 volts	-0.84	-0.58
77262 Boards, panels for electric distribution>1000 volts	-0.80	-0.77
77281 Bases for the goods of heading 7726, not equipped	-0.86	-0.37
77282 Other parts for apparatus of 7724, 7725 & 7726	-0.85	-0.57
Parts thereof	1991	2001
77611 Colour television picture tubes, cathode ray	-0.70	-0.07
77612 Monochrome television picture tubes, cathode ray	-0.54	-0.67
77621 Television camera tubes; image converters, intensi.	-0.53	-0.92
77623 Other cathode-ray tubes	-0.64	-0.77
77625 Microwaves tubes (excluding grid-controlled tubes)	-0.84	-0.94
77627 Other valves & tubes	0.41	-0.09
77629 Parts of the tubes, valves of sub-groups 7761, 7762	-0.90	-0.41
77631 Diodes, not photosensiti. nor light emitting diodes	-0.08	-0.54
77632 Transistors, dissipation rate < 1 w	-0.56	-0.67
77633 Transistors, dissipation rate > 1 w	-0.87	-0.56
77635 Thyristors, diacs & triacs	-0.74	0.03
77637 Photosensitive semi-conductor devices; light emitt.	0.41	-0.52
77639 Other semi-conductor devices	-0.31	-0.33
77641 Digital monolithic integrated circuits	-0.94	-0.79
77643 Non-digital monolithiques integrated circuits	-0.87	-0.76
77645 Hybrid integrated circuits	-0.62	-0.62
77649 Other electro. integrated circuits, microassemblies	-0.81	-0.38
77681 Piezo-electric crystals, mounted	0.25	-0.24
77688 Parts of the devices of 7763 & of item 77681	-0.67	-0.46
77689 Parts of the articles of heading 7764	-0.06	-0.49

Source: elaborated on OECD data