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STRIVING FOR INTERNATIONAL COMPETITIVENESS: LESSONS FROM ELECTRONICS FOR DEVELOPING COUNTRIES

by

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Technological Change and the Electronics Sector:
Perspectives and Policy Options for Newly Industrialising Economies

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RÉSUMÉ

Pour chaque pays qui entreprend de restructurer ou de développer sa compétitivité, l'électronique est devenu un secteur essentiel dont l'évolution a donné naissance à une industrie caractérisée par une croissance jamais atteinte en termes de vente et d'exportation, de capacité innovatrice et de prolongements techniques pour les services apparentés. Cependant, du fait de ses multiples possibilités d'application, l'électronique a également touché de nombreuses autres industries. Au lieu de miser seulement sur la concurrence au niveau des coûts, l'avantage compétitif est maintenant souvent acquis par ceux qui détiennent — temporairement — le privilège de la maîtrise de la production de technologies de pointe. On constate désormais un type d'innovation basé sur les liens avec les consommateurs, les échanges avec les fournisseurs, les sous-traitants, les universités, les associations industrielles, les instituts gouvernementaux et, par le biais de divers accords de coopération, même avec des concurrents potentiels. Ainsi, la compétitivité d'une firme vient non seulement de sa propre vitalité, mais aussi du support émanant de son environnement externe. Il est évident que ce support diffère d'une industrie à l'autre et d'un pays à l'autre.

Bien que les industries retardataires aient réussi une percée dans de nombreux groupes de produits électroniques, plusieurs branches de cette industrie viennent de connaître des mouvements de concentration et la mise en place de barrières protectionnistes importantes. Jusqu'à une date récente l'industrie électronique de masse a constitué une porte d'entrée pour les industries retardataires mais actuellement les normes de qualité et de fiabibilité ont restreint ces possibilités exclusivement basées sur un coût très bas. La bataille concernant les standards de la télévision de haute définition a placé les NEI en position de spectateur. Certaines d'entre elles, notamment Taiwan et Singapour, ont réussi dans la bureautique, succès dû à la réduction de la taille des entreprises, à la sous-traitance et au développement des systèmes de non-exclusivité, cependant on ne peut prévoir si les sociétés américaines et japonaises vont surmonter leur réticence à mettre sur le marché une nouvelle génération de produits tels que le micro-processeur 32 bits, les unités de disque dur de deux pouces et demi, les écrans de cristal liquide et les imprimantes à jet d'encre. Dans le secteur des communications les NEI ont été gagnantes dans l'équipement des terminaux mais cela n'a pas été le cas pour l'équipement des standards téléphoniques du secteur public où les barrières protectionnistes restent très fortes. Pour des raisons stratégiques des NEI comme Taiwan et la Corée ont accru la production des circuits intégrés, particulièrement les DRAMS (mémoire active dynamique). Dans ce domaine les perspectives restent décevantes et il est improbable que les derniers venus puissent générer des bénéfices. Dans l'industrie des logiciels la quasi-absence de restriction en matière de capital, l'intensité de la main-d'oeuvre disponible associée à des salaires bas et à une accumulation de commande sont neutralisés par le manque de personnel qualifié et maîtrisant l'anglais. Par ailleurs, non seulement la production mais aussi la diffusion de l'électronique de pointe impliquent un niveau suffisant de compétences technologique. Par exemple, les technologies avancées, reconnues comme un élément de base de la compétitivité, sont à peine utilisées dans les pays en développement à cause de la dimension des investissements nécessaires, de l'abondance d'une main-d'oeuvre bon marché, de structures organisationnelles obsolètes et surtout de l'absence de compétences nécessaires.

Outre ces possiblités et contraintes liées à l'industrie, chaque pays a ses propres particularités historiques, économiques, politiques et géographiques qui le rendent plus ou moins apte à s'insérer dans l'industrie électronique d'une manière globale. Les chefs de file des NEI asiatiques (la Corée, Taiwan, Singapour et Hong Kong) sont à l'évidence les mieux placés dans la concurrence avec les firmes basées dans les pays de l'OCDE. Cependant, même ces pays sont désavantagés par la limitation de leur potentiel technologique alors que l'émergence du second groupe de NEI asiatiques (en particulier la Thaïlande et la Malaisie) nuit à leur compétitivité fondée uniquement sur le coût. Ce dernier groupe de pays a bénéficié d'un afflux d'investissement étranger favorable. Néanmoins, on ne sait si ces pays vont être en mesure d'intégrer dans leur propre économie ces investissements et cette technologie étrangère. Les NEI d'Amérique latine et de l'Inde sont confrontées à une situation particulièremant difficile. Leur traditionnelle orientation autocentrée a abouti à la création d'industries électroniques locales souvent inefficaces, excessivement diversifiées et produisant à coût élevé du matériel déjà dépassé. La libéralisation des échanges, y compris l'arrivée de sociétés étrangères, a déjà conduit à une rationalisation mais cette brutale évolution des politiques va sans doute laisser des traces comme l'affaiblissement de l'appareil de production d'un pays.

Une conclusion presque inévitable s'impose : les perspectives de compétition dans le secteur de l'électronique sont extrêmement limitées pour la majorité des pays en développement. On trouve dans l'industrie de l'électronique une illustration du concept selon lequel la compétitivité est un processus cumulatif, favorable aux pays qui disposent déjà d'une main-d'oeuvre qualifiée, d'une bonne infrastructure, d'un marché local viable et d'un réseau de fournisseurs et de filiales associés à l'investissement étranger. Pour les derniers venus la conquête de la compétitivité dans l'électronique signifie d'abord la création d'un potentiel technologique local qui doit aller de pair avec l'accès à la technologie étrangère, aux investissements et aux marchés.

SUMMARY

Electronics has become critically important in every country's attempt to restructure or build its competitiveness. The developments in electronics have given rise to an industry with an unprecedented growth record in terms of sales and exports, innovative capacity, and spin-off potential for related services. But electronics has also infiltrated into many other industries through the pervasiveness of its application potential. Instead of competing solely on cost, competitive advantage is now often obtained by those who have the (temporary) benefit of having mastered cutting-edge technology. To the fore has come a type of innovation that builds on relations with users, on interaction with suppliers, subcontractors, universities, industry associations, government institutes, and even potential competitors through various kinds of co-operative agreements. Thus, the competitiveness of a firm depends not only on its own strength, but also on the support it receives from the external environment in which it operates. Clearly, this support varies markedly from industry to industry and from country to country.

Even though industrial latecomers have realised successful entry in a number of electronics product groups, most parts of the industry have recently witnessed concentration and higher barriers to entry. The consumer electronics industry has been until recently a point of entry for industrial latecomers but now quality and reliability requirements have diminished the possibilities based exclusively on low costs. The battle on HDTV standards has turned the NIEs into mere bystanders. Some NIEs, notably Taiwan and Singapore, have been successful in the office automation industry, thanks to downsizing and outsourcing, and the development towards open non-proprietary systems. It remains to be seen, however, whether US and Japanese companies will give up their reluctance in making available new generation products like 32-bit microprocessors, 2.5 inch hard-disk drives, liquid crystal displays and ink-jet printers. In communications, the NIEs have been quite successful in terminal equipment, but this has not been the case in the public switching equipment industry where entry barriers are notoriously high. For strategic reasons, NIEs like Taiwan and Korea have become active in the production of integrated circuits, especially DRAMs. Prospects in this particular industry, however, are daunting, and it is unlikely that industrial latecomers will be in a position to generate any profits in this area. In the software industry, low entry barriers in terms of capital requirements, labour intensiveness in combination with the low-wage advantage and large backlogs are offset by the scarcity of an educated and preferably English speaking labour force. Besides, not only the production but also the diffusion of advanced electronics requires a sufficient technological capability. Advanced manufacturing technologies for example, a widely accepted tool in constructing competitiveness, are hardly used in developing countries because of the size of required investment, the abundance of cheap labour, outdated organisational structures and above all the lack of appropriate skills.

In addition to these industry-related opportunities and constraints, every country has its particular historical, economic, political, and geographic features that make it into a more or less suitable player in the global electronics industry. The first-tier Asian NIEs (Korea, Taiwan, Singapore, and Hong Kong) are undoubtedly in the

best position to compete with OECD-based firms. But even these countries are handicapped by their limited technological potential, while the rise of second-tier Asian NIEs (particularly Thailand and Malaysia) prevents them from competing solely on cost. This latter group of countries has benefited from a surge in inward-bound foreign direct investment. But it remains to be seen whether they will be able to absorb foreign technology and investment into the local economy. The Latin American NIEs and India face a particularly difficult situation. Their traditionally inward-looking orientation has led to the emergence of domestic electronics industries that are often inefficient and excessively diversified, while producing outdated models at high cost. Trade liberalisation, including the entry of foreign firms, has already led to rationalisation, but the sudden policy shift is likely to leave scars, like the weakening of a country's technological base.

An almost unavoidable conclusion is that prospects for competing in electronics are very limited for the majority of developing countries. The electronics industry exemplifies the argument that constructed competitiveness is cumulative, benefiting those countries that have already developed a skilled workforce, good infrastructure, a viable home market, and a network of suppliers and related firms in combination with foreign investment. For industrial latecomers, striving for competitiveness in electronics means above all that the construction of an indigenous technological capability has to proceed in concordance with access to foreign technology, investments, and markets.

PREFACE

This synthesis paper poses the essential question whether developing countries can catch up in — or alternatively through — electronics.

The electronics industry is characterised by a range of sectors and product groups, each with their own dynamics and their own 'rules of the game'. Besides, every country responds in a different way to these challenges, depending on history, income situation, industry structure, policy orientation, etc. In addition, the international situation evolves constantly, and usually not to the advantage of developing countries.

The relevance of international competitiveness for developing countries increased during the 1980s and is likely to continue to do so in the 1990s. Limited domestic markets, failure of inward-looking development strategies, success of export-based growth, widespread and severe balance of payments problems and indebtedness, as well as continuation of structural adjustment and trade liberalisation schemes have left large parts of the developing world with no other option than trying to export on the world market, a market where new entrants are not particularly welcome and where competitiveness has proven to be the key to success. Using the latest insights, the author points out that constructing competitiveness in electronics is a long and painful process in which the role of the international community is pivotal — as foreign investor, as technology source, and as strategic market.

This paper synthesises some of the main findings and conclusions of a research project on "Technological Change and the Electronics Sector — Perspectives and Policy Options for Newly Industrialising Economies", undertaken at the OECD Development Centre. The purpose of this project has been to analyse how technological change and globalisation of competition affect barriers to entry and the scope for latecomer strategies in the electronics industry, and what this implies for firm strategies and government policies in different NIEs.

This paper deserves dissemination for at least three reasons. Firstly, it guides the interested reader to the underlying publications that are documented in section 6 of this paper. Secondly, it gives an accurate overview of the current developments in the rapidly-changing electronics industry, and the role of industrial latecomers in it. Thirdly, it is an interesting contribution to the on-going debate on the relationship between technology and development.

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I. INTRODUCTION

Why focus on electronics as a pathway towards building international competitiveness? Surprisingly, approaches to the relationship between electronics and development are highly divergent. At one side, it is argued that developing countries are too far behind to benefit from such an advanced technology as electronics. In this view, investing limited resources in a technology beyond one's reach would have nothing less than catastrophic consequences. At the other side, it is argued that electronics offers such a huge potential for productivity enhancement that developing countries cannot afford to neglect this industry.

One reason for this wide disagreement is that both sides emphasize quite different aspects of electronics. On the one hand, the developments in electronics have given rise to an industry with an unprecedented growth record in terms of sales and exports, innovative capacity, and spin-off potential for related services. The enormous potential of the electronics industry is illustrated by Table 1, showing the product groups with the fastest growing trade: the first three places are occupied by electronics-related product groups. This reality is in itself reason enough to raise the question, what role can developing countries play in this promising industry? Therefore, much attention will be focused on whether and how developing countries can compete **in** electronics.

Table 1. **Imports of the 10 fastest growing products for all market economies**

	SITC/ Rev.2 number[a]	Product group	Value 1988 ($ bn)	Average annual change 1979-88
1.	**751+752+759**	**Office machines, data processing equipment, parts**	**104.2**	**18.7%**
2.	**776**	**Transistors, valves, etc.**	**50.6**	**17.1%**
3.	**764**	**Telecom equipment, parts and accessories**	**45.7**	**14.8%**
4.	714	Engines and motors, n.e.s.	16.5	14.5%
5.	874	Measuring and controlling instruments	32.4	12.4%
6.	894	Toys, sporting goods, etc.	19.2	11.4%
7.	792	Aircraft	38.3	11.1%
8.	84	Clothing	87.6	11.1%
9.	541	Medicinal, pharmaceutical products	32.0	11.1%
10.	**772**	**Electrical apparatus for electrical circuits, etc.**	**28.3**	**11.0%**

a. SITC/Rev.2 75/76/77 are parts of the electronics industry.

Source: Based on GATT, *International Trade 89-90* (Vol.II), Table IV.2.

On the other hand, electronics has infiltrated into many other industries through the pervasiveness of its application potential. Industrial electronics has literally invaded the capital goods sector, playing an important role in restructuring every country's competitiveness[1]. For instance, several industrial product groups in which

trade is growing rapidly, such as aircraft, measuring and controlling equipment, and engines and motors, increasingly embody electronic parts and components. The on-going process of automation, for example through automated manufacturing technologies, requires special attention from those countries that have based their competitiveness solely on low labour costs. The question whether and how developing countries can compete **through** electronics is therefore crucial as well.

Beyond this dichotomy between competing in versus through electronics, the project has addressed five key questions: (1) why were certain NIEs able to compete as producers of electronics goods and services, and will they be able to do so in the future? (2) what have been the main barriers confronting entry strategies into different sectors of the electronics industry, how are they affected by technological and organisational innovations, and by the globalisation of competition? (3) what factors condition international competitiveness in this industry? (4) what are the chances for different groupings of developing countries to spread the application of new information technologies, and thus to reduce the technology diffusion gap which separates them from most OECD countries? and (5) how do these findings affect the current debate on the reform of the international regulatory framework for international trade, investment, and technology flows?

The following discussion puts forward important ideas towards answering these ambitious questions, without having the pretention to answer all of them completely. Section II describes the main elements of international competitiveness. Are developing countries competitive, and is the choice for electronics an opportunity to gain competitiveness? Section III identifies the windows of opportunity in electronics, especially by focusing on barriers to entry. This section presents sketches on several sectors and product groups within electronics. Developments will be examined for consumer electronics, office automation equipment, communications, electronic components and software. Industrial electronics can increase competitiveness in its function as a capital good, as illustrated by a brief discussion of automated manufacturing technologies from the perspective of the user. Section IV takes a somewhat different perspective, looking at recent experiences of those developing countries that have embarked upon electronics. Due to diverging experiences, it is necessary to distinguish between the episodes of first and second-tier Asian NIEs, first and second-tier Latin American economies, and the case of India. Section V draws some major conclusions. It tries to answer the question whether recent developments in both the electronics industry and in the international environment have opened up or barred new pathways to development, and which pathways can be recommended. In addition, some final recommendations are made on trade, industry, and science and technology policy.

II. INTERNATIONAL COMPETITIVENESS AND DEVELOPMENT

During the 1980s, the idea that productivity growth enhances international competitiveness, GNP growth, and job creation has become widely accepted. This new notion of international competitiveness goes beyond the older and by now questionable proposition that a competitive position of a country goes necessarily hand in hand with a favourable trade balance[2].

Towards a concept of competitiveness

As a starting point, competitiveness for a nation will be defined as the degree to which it can produce goods and services that meet the test of international markets, while simultaneously maintaining and expanding the real incomes of its citizens[3]. The literature emphasizes at least three important attributes to competitiveness[4]. Firstly, competitiveness is built on the (micro) level of the firm and translated to the national level only in a subsequent stage of analysis. Secondly, competitiveness is increasingly technology-driven. Thirdly, competitiveness is often created through non-market interactions, such as government intervention and certain inter-firm transactions.

The term competitiveness has originally been used in a microeconomic sense, relating to a firm's capacity to gain market shares, increase its profits, and expand. A firm can adopt several strategies when it wants to pursue competitiveness. Major differences are between strategies that compete on cost and those that do so on differentiation. In addition, there are strategies with a broad or a narrow (niche) target. The business literature argues that a firm has to make strategic choices between these alternatives, not trying to pursue all strategies simultaneously. If a firm does not make such choices, it risks being positioned in the middle between competition on cost and on differentiation, which usually is regarded as a dangerous position[5]. Yet, the practice of competing in electronics is often different; firms in practically every sector of this industry "...have to cope with more complex and often contradictory requirements, where price and non-price forms of competition are closely intertwined. As a result, the trade-offs and risks involved in the choice of competitive strategies have dramatically increased[6]."

The second attribute of international competitiveness relates to the role of technology. Firms have to innovate continuously if they want to compete successfully. Upgrading or renewing existing products and introducing improvements and reorganisations in product lines are very important tools for surviving in a competitive environment. Innovation is therefore to be seen at the core of competitiveness. Recent thinking about innovation has helped in understanding the nature of competitiveness. Innovation is a complex process that is to a high degree driven by the fundamental requirements of competition. Innovation is not just an outcome of research and development in stand-alone corporate laboratories, but a mechanism that builds on relations with users, on interaction with suppliers, subcontractors, universities, industry associations, government institutes, and even on interaction with potential competitors through various kinds of corporate agreements. The firm finds itself placed in a network of relations through which it contributes to the on-going

process of technological change. This interactive process is iterative, incremental, and cumulative[7], making those competitive who have the (temporary) benefit of having mastered cutting-edge technology.

But the cumulativeness of technology has its limits. A new so-called 'technological paradigm' can come into place and although its 'frontier' might be far behind, it can have a large technological potential that threatens the existing paradigm. Whenever a technological paradigm changes, the established knowledge base can suddenly be devalued, and one has to start accumulating new sorts of knowledge. Under such circumstances, overtaking by new competitors is a real possibility, not by 'racing behind established competitors at the technological frontier, but by running in a new direction'[8]. Changes in technological paradigm can provide windows of opportunity, also to those who have not been among the frontrunners within established paradigms. As these changes take place, lagging countries can become less handicapped, since barriers to entry tend to be relatively low in a transitory phase, and since they are learning at the same time as every other country[9].

However, there are important limitations to these ideas, commonly referred to as the notion of 'technological leapfrogging'. Most importantly, not every country has a similar ability to learn. The pace of learning depends upon the complexity of the knowledge involved but also on the initial capabilities of the learner. Much, therefore, depends on a country's 'technological capability', which is the entire complex of human skills (entrepreneurial, managerial, and technical) needed to set up and operate industries efficiently over time[10]. The availability of high level scientific and technical personnel in even the most advanced NIEs should not be overemphasized, and the scientific infrastructure may therefore not be adequate to support such a leap[11].

The third attribute of international competitiveness, non-market interactions, consists of two components, namely inter-firm transactions and government intervention. The 1980s have witnessed a sharp increase in the first component, as expressed by various forms of inter-firm co-operation. Joint ventures, strategic alliances, technology-swapping, and cross-licensing agreements all bring about transactions outside the market place. The tendency towards strategic partnering is likely to have led to concentration and increasingly oligopolistic market forms. Many more non-market interactions have come from governments. Although competitiveness is primarily found at the level of the firm, it is driven by innovation that requires interaction with the external environment. The competitiveness of the firm depends therefore not only on its own competitive strength but also on the support it receives from the external environment in which it operates[12]. It is for this reason that governments play an important role: they treat trade, industrial and science and technology policy as weapons of international competition. These different policy strands are especially blended when it comes down to the support of strategic industries like advanced electronics, in Japan, the United States, and Western Europe alike. The term 'neo-mercantilism' is an appropriate label for the increasingly politicised nature of competition, implying that rivalry among firms is also rivalry among (national) systems[13]. Some have used the term 'structural competitiveness' to emphasize the importance of the external environment, since the firm's competitiveness depends largely on long-term trends in a national economy's productive structure, its technical infrastructure, etc[14]. In this context, the more neutral

term 'constructed competitiveness' will be used. It emphasizes the cumulative, learning, and dynamic foundations of technological advances on which competitiveness is built[15].

Are developing countries competitive?

Competitiveness varies widely from country to country and from sector to sector. The use of determinants of competitiveness has become widely accepted as a way of measuring these differences and identifying major strengths and weaknesses. In the case of electronics, five of these determinants have been singled out: (1) markets for production factors, in particular advanced factors like skilled labour and venture capital; (2) the nature of demand for electronic goods and services; (3) firm strategies and industry structure; (4) the state of development of supplier networks and related industries; and (5) the policy, institutional, and regulatory framework for developing an electronics industry[16].

Judged by these determinants, the prospects are not very promising for most developing countries. Shortages of skilled labour are usually severe, especially regarding electronic engineers and technicians. Capital markets are often repressed or hardly existent, although changes are under way. Infrastructure, especially communication infrastructure, is commonly in a poor state, overburdened, or lacking reliability. Furthermore, home markets are often small and underdeveloped, as exemplified by figures on per capita consumption of electronic goods and services in OECD and non-OECD countries. In addition, supplier industries are often constrained, making the import of intermediate goods indispensable. Industry structure and firm organisation as well as the policy framework vary greatly from country to country. Overall, this list of determinants contains numerous weaknesses, and shows how many problems developing countries have to overcome when aspiring to the construction of a competitive electronics industry. African countries fall out quickly, and are unlikely to play a substantial role in electronics in the near future[17]. The determinants of national competitive advantage give somewhat more hope for certain Latin American and especially Asian countries. It is for this reason that this project has focused on these two continents.

Where do developing countries start, when constructing competitiveness? Since competitiveness is to a great extent built on innovations, and since the innovation process is largely cumulative, it follows that constructing competitiveness takes much time, decades rather than years. Most OECD countries have had time to build their competitiveness, but this has not been the case for most developing countries. Therefore, not many developing countries have come very far in this process of building competitiveness[18]. Yet, it would be an exaggeration to conclude that developing countries have to start from scratch. Historical, geographical, cultural, and political processes all count and make up a country's strengths and weaknesses on which a strategic choice for future development should be based. Clearly, developing countries with limited technical and human capital resources have to be cautious when making such choices, especially since building competitiveness will draw upon these limited resources for an extended period of time. Therefore, it would be wrong to conclude from the preceding discussion that competitiveness can be constructed anywhere, and at the same time in several industries.

Few, if any, countries have become internationally competitive without external support. The inflow of technology and capital is usually indispensable in this process. Foreign direct investment, bringing in both technology and capital, can have a trigger-effect and set into motion a process of accelerated development. Initially, foreign direct investment tends to be lured by low production costs, especially through low wages. However, other factors, namely those specific to national strengths, are necessary to hold on to international capital, that is often 'footloose' in nature. Non-cost factors become increasingly important when a nation's development strategy succeeds, allowing for an increase in a standard of living through higher wages and therefore higher production costs. This may cause foreign investors to search for rival countries that offer even lower production costs. A common macroeconomic correction to prevent such an out-migration is devaluation of a country's currency. However, devaluation lowers a nation's standard of living because it makes imports more expensive while reducing the prices obtained abroad for its products and services[19]. Currency devaluation is therefore often a 'quick fix', and of no great help in a strategy that intends to upgrade a nation's economy in the long run.

Attracting and holding on to foreign direct investment is only one avenue to getting access to technology, albeit an important one. Alternatives range from imports of capital goods to licensing, original equipment manufacture, second sourcing, co-operative agreements and acquisition of foreign innovative start-ups[20]. Technology imports, regardless their form, are of great importance for developing countries, since they allow them to become familiar with existing techniques on the basis of learning, a process that is common to all late industrialisers. Foreign technology is often dissected, reverse engineered, and subsequently imitated. The difficulties for a developing country in gaining mastery of a known technology should not be underestimated[21]. The pre-existing technological capability of many developing countries is often too limited to absorb successfully the imported technology.

How does technological change, finally, affect this difficult process of building competitiveness in developing countries? Two conflicting answers can be given. Firstly, as shown before, technological change leads to new products and industries, sometimes replacing an older technological paradigm, and offering windows of opportunity to new rivals, the so-called latecomers. Yet, there is mounting evidence, including the results of this project, that technological change tends to widen rather than narrow the gap between countries[22]. The cumulative nature of technical change, benefiting those who already have a certain technological capability, is at the core of such polarisation effects, hampering developing countries with their low score on most of the determinants of competitiveness. Whether technological change is beneficial or detrimental to developing countries often depends on the dynamics of entry barriers and the specifics of the industry under study, as will be shown in the following section.

III. TRENDS AND ENTRY-BARRIERS IN ELECTRONICS

No country can be competitive in all segments of the electronics industry. Even leading countries such as the United States and Japan are lacking competitiveness in a range of products. This section will show that there are numerous trends in electronics that have an impact on the opportunities for latecomer strategies.

The dynamics of electronics have generated many new products and even entirely new product groups in which successful entry by industrial latecomers has been realised (Table 2). Successes have been quite different from sector to sector, and from period to period. One of the main questions of the project has been whether the changing dynamics of entry barriers have facilitated or restricted access to the electronics industry. As a matter of fact, many parts of the electronics industry have witnessed increasing concentration and increasingly high barriers to entry, painfully demonstrating the temporary nature of a window of opportunity. It can be argued that an electronics based technological paradigm has been put into place by now. Barriers to enter the industry, being low in a transitory phase, are expected to rise once this stage draws to a close. For instance, economies of scale and economies of scope will rise. In general, large and established companies are better placed to benefit from these economies than smaller ones. The existence of threshold barriers is a case in point. If the minimum efficient scale of operation is high in relation to the market, new entrants are forced to produce large quantities that cannot be absorbed by demand. Price and profit erosion are probable consequences for all producers alike. But a sound financial basis and a balanced product mix allow larger companies to sustain such a profit squeeze for a much longer time than small and vulnerable entrants.

There are many entry barriers outside the sphere of production as well, such as in R&D, procurement, and marketing. 'First mover advantages' are critical in this respect. Such advantages can be expressed in terms of costs, quality, market intelligence or speed-to-market. Quick movers also have the advantage of defining product standards, to which latecomers have to conform. Much depends on access to networks, whether in technology, in the sourcing of materials or in marketing. Networks are particularly important in obtaining access to core components, channels for sales, maintenance, and repair. In addition, access to markets is restricted due to another set of entry barriers: regulatory barriers that are heavily influenced by government action. Discriminatory access to government procurement markets, restrictions on access to knowledge through intellectual property right protection, and restrictions on foreign direct investment are just a few examples[23].

Table 2. **Electronic products in which successful international competition from NIEs has been registered**

Successful latecomer entry realised	No successful latecomer entry realised
Consumer products	
* televisions (B&W and colour)	* high definition television
* video cassette recorders	* digital audio tape (DAT) recorders
* audio equipment	
* car radios	
* electronic games/watches	
* microwave ovens	
Office automation equipment	
* personal computers	* mainframe and super computers
* keyboards	* mini-computers
* monitors	* copiers
* dot matrix	* hard-disk drives (2.5 inch)
* hard-disk drives (3.5 + 5.25 inch)	
Communications	
* telephone sets	* public switching eqpt. (exc. Korea)
* private switching equipment	
* facsimile	
Electronic components	
* discrete semiconductors	* EPROMs
* DRAMs (Korea and Taiwan only)	
* SRAMs (Korea and Taiwan only)	
* printed circuit boards (multi-layer)	
Software	
* contract services	* systems integration
* ASIC design	* standard packaged software

Source: Largely based on Ch. IV, D. Ernst and D. O'Connor, *Competing in Advanced Electronics*.

Consumer electronics: A classical point of entry[24]

This segment of the electronics industry has an estimated world market of $70 billion in 1989, equalling 11 per cent of the total market for electronics equipment[25]. This percentage used to be much higher (20 per cent in 1974), which illustrates that the pace of growth in consumer products has been much slower than in other segments. Yet, this particular segment has a special significance, since it has traditionally been the point of entry for industrial latecomers that have the ambition to become a player in the electronics industry. The industry has been dominated by the production of video equipment, like colour TVs and video cassette recorders (VCRs). Important products in audio equipment are radios, tape recorders, stereo sets, and car radios. Other personal and household electronics range from calculators, games and microwave ovens to electronic watches, clocks and (electronic) musical instruments. Most consumer products are relatively mature, and the growth of their market has been limited compared to other segments, with fierce price competition as a

consequence. Japan exercises a dominant position in this part of the industry, followed by the four Asian NIEs (especially Korea). A few European players have had major problems and have undergone considerable restructuring in order to survive[26]. The absence of the United States as a supplier of consumer products is striking, an outcome of earlier movements to more promising and profitable sectors of the electronics industry. Some of the more important products of this sector, namely televisions, VCRs, and high definition television will now be briefly addressed.

Television sets have been the most important product group within this sector for quite some time. Black and white televisions are at the very end of their life cycle. They do not play any significant role any more, except in certain less-developed and well-protected markets like India where the number of black and white TVs produced still outstrips that of colour TVs. But even colour TVs are becoming a less and less important part of the consumer products mix. Colour TV production is scale-intensive, due to fixed investments in tooling, automated assembly and testing equipment. Estimates of minimum efficient scale for a colour TV plant are imprecise, but probably around 400 000 units per year at the very least. Certain critical components such as colour picture tubes or cathode ray tubes, often disconnected from assembly, have a much higher minimum efficient scale.

A somewhat more recent product is the VCR, whose production started in the late 1970s and peaked in the mid-1980s. As with colour TVs, price competition is stiff and parts of VCR production take place in low-cost locations in Asia, often through foreign direct investment by the leading Japanese and to some extent European suppliers.

A revival of interest in the consumer products industry is noticeable now that the development of high definition television (HDTV) has reached the pre-commercial stage. HDTV is considered to be a strategic product that embodies several cutting-edge technologies from different fields, and has the potential to generate many spin-offs for other parts of the industry. The emergence of HDTV demonstrates clearly that competition takes place not only between firms, but also between countries. The major global players are engaged in research consortia or make efforts to set their own standards. European companies are working together in the framework of Eureka's HDTV project, backed by the European HD-MAC standard, with D-MAC and D2-MAC as more recent, intermediate, off-springs. Japanese firms have developed a different (MUSE) standard. Attempts to make the Japanese system compatible with a forthcoming US HDTV standard have been made with the launch of Clear-Vision (EDTV) — as an intermediate step — and by gradually revising the MUSE format to match the US proposal. The final selection of a US HDTV standard is not expected at least until 1993. Although the Federal Communication Commission (FCC) is now testing and giving intermediate guidance, this delay impedes a concrete development of HDTV equipment by US companies. This lack of direction from the US Government limits the chance of success for US firms to re-enter the consumer electronics market through HDTV[27].

The unresolved standards issue, partly a result of deliberate entry deterrence strategies, makes entry into the HDTV field extremely difficult for NIE firms. Given the fact that NIE firms are not in a position to set global standards, all they can do is

monitor the developments and try to acquire as much relevant technology as possible. The only hope for the NIEs comes from the urge to set global standards that might induce major competitors to license HDTV technology with more generosity than usual. With so many political and strategic aspects, it is quite possible that the outcome of the HDTV standards battle will lead towards 'a technology that is not necessarily chosen because it is efficient, but that becomes efficient because it has been chosen'[28].

The developments in the HDTV field show that the consumer electronics sector becomes more and more advanced, requiring access to technology and components that are not always readily available to newcomers. Quality and reliability requirements have increased, while possibilities to focus on low-cost, low-quality market segments have considerably declined. This fact, in combination with modest market perspectives and fierce competition, has made the consumer electronics industry into a questionable entry point for industrial latecomers.

Office automation equipment: Niches for latecomer entry[29]

Office automation equipment is the largest segment of the electronics industry. The size of the market was $189 billion in 1989, has grown strongly in recent years, and makes up 30 per cent of the total electronics equipment market. By far the most important product group is electronic data processing (EDP), including the computer market, off-line equipment, accessories, parts, and auxiliary equipment. Other office equipment includes electronic typewriters, calculators, and cash registers.

In contrast to consumer products, the United States has traditionally dominated the office automation equipment business, by taking advantage of first mover advantages and by competing on technological differentiation based on ongoing innovation. Until a few years ago, both European and Japanese companies played a secondary role in the industry. The role of European companies seems to have declined further, but Japan has successfully entered a large number of product groups in the computer industry. Taiwan, Singapore, Hong Kong and Korea have been successful entrants into several niche markets of the industry, although Korea has been a relatively weak player when compared to its performance in other sectors. We will focus now on the products that have turned out to be promising entry points for NIE firms.

The emergence of personal computers (PCs) in the early 1980s was a logical outcome of a process of 'downsizing' of computer systems. Due to progress in integrated circuit (IC) technology, ever smaller and more powerful computers were launched, from mainframe and minicomputers to personal computers and laptops. While IBM dominated the market for large-scale computers, this was less the case for personal computers. IBM was late in launching its PC-line, long after Apple for instance, and was therefore unable to exercise a virtual monopoly as it did in mainframe computers. As downsizing has led to a decline in the number of components and less complicated configurations, barriers to enter the industry have decreased. A large number of actors have emerged on the scene, most of whom

have taken up the role of assembler, licensing one or another version of a DOS-compatible operating system. Computer firms manufacture only a limited number of parts on their own, and source externally up to 90 per cent of the total value of shipments.

As in the case of HDTV, a lack of standards has seriously retarded the development and the application potential of computers. Suppliers attempted to 'lock in' customers in proprietary computer systems, preventing them to purchase from rivals with non-compatible architectures. The increasing dissatisfaction of customers with this situation has finally pushed computer companies to switch to open, non-proprietary, standard systems. Yet, the launch of UNIX as a proposed industry standard has not brought an end to the standardisation conflict. Two contending versions of UNIX have been proposed, one by AT&T and one by IBM, each with a similar market force behind them. It is hard to foresee if any of the leading operating systems, MS/DOS or either UNIX version, will eventually prevail. The hook-up between IBM and Apple could turn out to be a decisive factor in this battle. Indeed, competition in computers has turned out to be a multidimensional contest; not only price and performance, but also standards have emerged as a weapon of competition[30]. Imposed standards lead to an increase of barriers to entry, and virtually exclude those firms that have bet on the 'wrong' standard from the arena of competition.

Both the partial tendency to lower barriers to entry as an outcome of downsizing, and the tendency towards open non-proprietary systems have enabled a limited number of NIEs to penetrate the PC market, with Taiwan taking the lead. This window of opportunity was partly related to IBM's late start in PCs, forcing it to adopt an open architecture as a way of overcoming latecomer disadvantages. This strategy, joined by a liberal supply policy of the dominant microprocessor producer, Intel Corp. of the United States, permitted certain NIE firms (e.g. Acer and Tatung from Taiwan) to copy or 'clone' IBM PCs. Since ICs and other components are sourced outside, scale economies are not as important as in consumer products. Experience from NIEs shows that production levels of 100 000 PCs per year are not uncommon, although several companies produce substantially more. More so than scale requirements, knowledge about user requirements, speed-to-market, and a quick response to new technological opportunities and niches are by far the most important factors of success.

The increasing tendency among major computer firms to outsource their component and peripheral production has been beneficial for a selected number of NIE-based firms. Disk drives, enhancement cards, monitors, terminals, printers, and keyboards have increasingly been sourced from Taiwan and Singapore, often on the basis of OEM agreements. One of the advantages of OEM arrangements is that contractors have to provide much relevant technical information to the producing firm, which is an important means of technology transfer. Another advantage is that economies of scale, which are especially large for disk drives, are easy to achieve since OEM arrangements usually imply large orders.

Now that these NIE firms have mastered the technology of making most of the conventional computer peripherals and components, they are faced with two major

problems. First, the OEM business has given them limited brand name recognition and therefore not much room to market under own brand names. Second, such new generation products as 32-bit microprocessors, 2.5 inch hard-disk drives, liquid crystal displays and ink-jet printers impose new technological barriers to entry. Since this technology is in the hands of only a few US and Japanese companies which are for the present reluctant to license or supply parts, the possibilities for technological upgrading remain limited for these NIEs.

Communications: Heterogeneity in entry barriers[31]

The world market for communication equipment was around $137 billion in 1989, 22 per cent of the total electronic equipment market. A significant part of this market consists of military electronics, such as radar and navigational aids. This part has not been considered in the project.

The discussion will therefore be focused on telecommunications equipment, a diverse segment that ranges from public switching equipment to terminal equipment such as telephone sets, key phones, facsimiles, and modems. Experience from Taiwanese and Hong Kong firms shows that entry barriers, mainly economies of scale, for the manufacturing of terminal equipment such as simple corded or cordless telephone sets, feature telephones, and answering machines are low, accessible even for small firms. This is not so for facsimile machines, where technology is evolving very rapidly and mainly in the hands of Japanese companies. Given the rapid pace of innovation in this industry (towards laser printer-type machines and plain paper faxes), NIEs might find it increasingly difficult to keep pace with the technological leaders.

Public switching equipment is an even more difficult industry to enter, due to considerable development costs and inherent system complexity. The highly competitive market for public switching equipment seems to leave hardly any room for the already existing rivals such as Alcatel, NEC, AT&T, Ericsson, Northern Telecom, and Siemens. Successful entry by NIE firms is difficult, but not impossible as shown by Korea. Brazil has made considerable efforts to develop its domestic production of public switching equipment in the framework of the Tropico family, but the domestic suppliers have substantial problems in competing abroad. India abandoned its indigenous development of electronic switching equipment in the early 1980s, after the underlying analogue design was not considered suitable any more. Entry barriers in the manufacturing of private switching equipment, such as electronic private area branch exchanges (EPABXs), are lower.

Components: Entry on the basis of strategic considerations[32]

The world market for electronic components was around $156 billion in 1989, 25 per cent of the total electronic equipment market. Its strategic importance derives from the fact that components are the physical building blocks for all other segments of the electronics industry. Although not necessarily correctly, semiconductor supplies are often considered important to control, for developed as well as for developing countries. Components for consumer products have generally been considered a preferred point of entry, since components for other industry segments used to have

higher quality and reliability requirements. This argument, however, may no longer be true due to the current shift towards highly reliable, high-quality consumer electronics products.

Among the three product groups of active, passive, and audio components, it is the first one that is regarded as the most 'critical' class of components. Integrated circuits (ICs) — semiconductors with more than one functioning element — have become the most important product in this segment, now that discrete semiconductors are becoming outmoded. Japan has overtaken the United States as the most important supplier of semiconductors, but its market share has stabilised now at a high level. In 1989, Japanese companies accounted for 54 per cent of all merchant IC sales, whereas this percentage was 52 per cent in 1990[33].

East Asian NIEs (especially Malaysia) have played their role in the semiconductor industry for quite some time already, even if it was through assembly and testing operations from multinational corporations that had their base elsewhere. Design and wafer fabrication are stages of IC production that are often harder to master. Taiwan and especially Korea have taken up the challenge of producing advanced ICs in an attempt to make their electronics industries more independent from outside sources.

Within the integrated circuit market, by far the greatest investments and efforts are made in the field of dynamic random access memories (DRAMs), memory chips with applications in PCs and other office automation equipment. Several generations of DRAMs move with an increasing speed through the product-life cycle. For example, US sales in 64-K DRAMs peaked in 1984, sales in the next generation 256-K DRAMs reached their peak in 1988, and 1-Mb DRAMs were the highest in sales in 1990. Mass production of 4 Mb DRAMs has started, while development of 16 and 64-Mb DRAMs is already in full progress. There is unusual pressure on each competitor to bring these ever more powerful memory chips to market as soon as possible. As recent experience has shown, first mover advantages in DRAMs are extraordinarily high, since premium prices can be imposed for only a very limited time. After that, prices fall sharply as rivals enter the market place, jointly supplying quantities that the market is unable to absorb. Hence, competition in DRAMs focuses primarily on reaching high volume sales in the early critical and high-profit stages of a DRAM generation's lifecycle[34]. As a consequence, staggering R&D costs (over $3 billion annually among the five leading Japanese companies in the field[35]) can never be recuperated by latecomers. Latecomers can avoid these R&D costs by licensing existing technology from the leading Japanese or US companies, but the prospects for long-term success in a product that fades out quickly are limited.

Despite these daunting prospects, several NIEs have made a commitment to the development and production of DRAMs, largely for strategic reasons. Taiwan suffered from shortages on the world market for DRAMs in the recent past, and has drawn its lessons from this experience. Taiwan's Acer recently started the production (wafer fabrication) of DRAMs on the basis of a joint venture with Texas Instruments. But the strongest NIE-performance in the DRAM field comes from Korea. An enormous dedication on the part of the leading and cash-rich *chaebol* in combination with licensing possibilities, especially from US firms, has enabled Korea's participation

so far, but the risks involved in DRAMs become increasingly high, probably too high for any other industrial latecomer. The question that comes to mind is whether the requirement of speed-to-market can ever be combined with a latecomer strategy based on borrowed technology in a field where first mover advantages are pivotal, where prices fall so quickly afterwards, and where products are so rapidly outmoded.

There are many more types of integrated circuits that would deserve some attention, such as static random access memories (SRAMs), reduced instruction set computing (RISC) chips, and erasable programmable read only memories (EPROMs), but the most interesting window of opportunity in the IC field is perhaps emerging in the form of Application Specific Integrated Circuits (ASICs). ASICs are customised or semi-customised ICs, designed for specific applications, allowing users to closely specify their wishes. There is a consensus about the growth potential of the international market for ASICs, a relatively new type of IC that has made a leap forward after the introduction of electronic design automation. In theory, this type of automation has freed designers from labour-intensive, repetitive tasks. This technology can have important consequences for industrial latecomers, allowing a 'decoupling' of the design phase from the manufacture phase. Barriers to entry in ASIC manufacture are high, but those for design have now become relatively low thanks to electronic design automation tools. Taiwan has already embarked on ASICs, and is developing its own independent local design sector[36]. Yet, it remains to be seen whether decoupling will become a widely used practice. Integration between design and fabrication might continue to be preferable because of the necessity of critical feedback, low co-ordination costs, and speed-to-market. In addition, close relationships between ASIC design and silicon foundries are very vulnerable in this highly cyclical industry, while the development of single-chip technology is likely to limit the potential of decoupling as well[37]. Finally, the importance of geographic proximity between users and designers/suppliers makes that decoupling is at the most likely to occur in those countries with a certain demand for ASICs, such as Taiwan, Singapore, South Korea, Hong Kong, and possibly Brazil or India.

Software: On growing pains and legal protection[38]

The size of the software industry is hard to measure; as a service sector it is excluded from statistics on electronics manufacturing. Estimates range from $70 to $180 billion in 1990, with a usually reliable Dataquest estimate of $100 billion. These figures indicate that the software industry has surpassed the consumer products industry in importance. If it is true, as some believe, that the worldwide market for software will grow to a level as high as $340 billion in 1996[39], it is likely to surpass many other sectors of the industry as well. The main tendency in software is that costs have risen almost as sharply as those in hardware have fallen. Hardware and software/service costs in computer systems are equal today, whereas this ratio was five to one in 1970. One of the reasons for this trend is the fact that the productivity of the software industry has not been raised to the same extent as in the hardware industry. Another reason relates to the increasing urge for ever more complicated systems integration which is needed to achieve communication between standard hardware components and custom software as well as between computer equipment

from different vendors. Still another reason for the relatively high prices is the fact that software is delivered on a sellers' market.

Trends in the software industry are partly a reflection of the dynamics in the computer industry. Downsizing (the trend towards smaller and more powerful computers) has its implications for software development. Packaged software for PCs, offered at attractive prices, has implied a trend away from customised production. The battle for operating system standards has had equal software implications. The trend of teaming-up among hardware companies is closely followed and answered by similar moves among software firms. Yet, the technological progress that has been characteristic for the hardware industry has not been followed by the software industry. Software remains a bottleneck, due to backlogs in application development, insufficient reliability of programs, and dissatisfying progress in achieving user-friendliness[40].

Until now, the software industry has been mainly in the hands of US-based companies, with some German, French, and UK firms playing a secondary role. Japan's performance in software has been relatively weak so far, and it is dealing more so than others with a 'software gap'. Korea, Taiwan, and India have been able to play supporting roles in certain parts of the software scene.

Current trends in software provide new opportunities but also new constraints for NIE firms. The low entry barriers in terms of capital requirement and the large backlogs make entry by NIE firms attractive, while the low wage advantage has a significant weight in such a labour-intensive industry. Equally strong constraints, however, have prevented NIEs from taking full advantage of these opportunities. Probably the most compelling one is the indispensability of an educated and preferably English-speaking labour force. Skilled personnel is the cornerstone of the software industry. The discussion on determinants of competitiveness demonstrated already that this is not a strong point for most developing countries, with the exception of several East Asian NIEs. India, with its pool of college-educated English speaking computer programmers, is an exceptional case. It exports annually $70 million in software and services, mainly in the form of programme reconversion work and exports of cheap but qualified labour, mostly to the UK. Prospects for other NIEs in the software business are not too encouraging. Built-up experience will play an ever-increasing role where future software problems are expected to become more and more complicated. The recurring overall reliability problem in software development is an additional reason for clients not to contract this delicate task out to countries that lack a quality-reputation.

The opportunities for NIEs to develop their software industries are even more constrained if the international trade environment is taken into account. As mentioned above, latecomer industrialisation is based to a high extent on imitation and replication. Although this practice can sometimes be beneficial for innovators (for instance in the case of standards battles), it is usually not. Software has been chosen as a field in which initiatives for strengthening and extending legal protection of creators have been concentrated. Developed countries, notably the United States — with high interests at stake — try to protect software as part of a larger effort to pursue intellectual property rights. A major example of this goal is the appearance of this issue on the agenda of the GATT Uruguay Round. Obviously, such initiatives, although fully

understandable from the creator's point of view, are not in the interest of developing countries. A major critique of current intellectual property right proposals is the choice to protect software on the basis of copyrights, rather than through trade secrets or contractual law. This form of protection is widely regarded as favourable to the author of software, through its universal and long-term applicability, hampering the widespread diffusion of software, and therefore discouraging the development of a viable, global software industry[41].

Industrial electronics: Perspectives from the user-side

This section shifts the attention from the producers to the users of (industrial) electronics. Such a shift is necessary since the application potential of electronics has been so pervasive. Every segment of the industry except consumer products and components enters the economy as a capital good. Office automation equipment, telecommunications equipment, software, and industrial control and instrumentation are each an example of the embodiment effect of technical change. As technical change proceeds, new generation equipment is launched. Although (at a macro-level) the introduction of new technologies has not been accompanied by increases in productivity growth — the so called 'productivity paradox' — it is hard to deny that (at the firm-level) newer capital embodies superior technology that is likely to be more productive than older capital[42]. The age and the 'quality' of the capital goods sector are important aspects that contribute to productivity growth and thus to the process of building competitiveness.

According to this line of reasoning, late-industrialising countries with limited amounts of past investment and high levels of present investment have the possibility of becoming competitive with a young capital stock with high overall productivity levels[43]. It has been demonstrated that advanced telecommunications offer an opportunity for rapid diffusion, mainly through the absence of a pre-existing telecommunications infrastructure. The fast adoption rate of digital switching equipment in non-OECD countries, especially in the Far East including the major NIEs, can be used as an example[44]. Yet, it looks like the diffusion pattern of advanced telecommunications is somewhat of an exception. In general, the diffusion of new technologies is affected by the strong cumulative effects of interrelatedness. Latecomers with lower levels of penetration are therefore likely to have lower rates of diffusion as well[45].

The importance of electronics as a capital good in constructing competitiveness is probably most pronounced in the case of advanced manufacturing technologies (AMT). Advanced manufacturing technology is computer-controlled or micro-electronics-based equipment used in the design, manufacture or handling of a product. Typical applications include computer-aided design (CAD), computer numerical control (CNC) machine tools, and robots. AMT can be an important means of cost reduction, while product quality, speed-to-market, and flexibility are equally important attributes, making AMT into a powerful tool for building competitiveness. The introduction of automated manufacturing technologies is therefore an important process innovation. Data on the diffusion of AMT hint at enormous differences in adoption rates, best-performing countries using more AMT than other nations. For instance, the density of robot use in manufacturing in 1988 was 118 per 10 000 in

Japan, 40 in Sweden, 29 in Italy, 26 in Germany and substantially lower rates in all other OECD countries[46]. Data on non-OECD countries are scanty, but point to even lower AMT densities. In 1985, NIEs had 8.5 times fewer numerically controlled machine tools per engineering sector employee than OECD countries, 8.3 times fewer CAD systems, and 43 times fewer robots[47]. Singapore, Korea, and Taiwan are the leading NIEs in the diffusion of automated manufacturing technologies.

How can NIEs close this huge technology diffusion gap with OECD countries? Many barriers to the introduction of AMT can be mentioned, like the size of required investment and the abundance of cheap labour. Experience from OECD countries points to a lack of appropriate skills and outdated organisational structures as the greatest bottleneck[48]. Thus, not only the production but also the diffusion of advanced electronics requires a sufficient technological capability when striving for competitiveness.

IV. EXPERIENCES FROM DEVELOPING COUNTRIES: ON STRATEGIES AND REALITIES

The experience of those countries that have succeeded in competing in electronics provides a good basis for policy recommendations on electronics and development. Even within the group of NIEs, there exist substantial differences in terms of production and export performance, as well as in the role of electronics in the national economy (Table 3A). There are also large differences in market size, imports, and indicators like the numbers of televisions and telephones per 1 000 inhabitants (Table 3B). A country classification has been made in which special attention has been given to the criteria of production structure, market size and structure, degree and form of reliance on foreign technologies, the role of the state, and indigenous scientific and technological capabilities. These criteria closely resemble the determinants of competitiveness mentioned earlier. On the basis of these criteria, a distinction can be made among first-tier Asian NIEs, second-tier Asian NIEs, first-tier Latin American NIEs, and second-tier Latin American NIEs. India is treated as a case apart[49].

First-tier Asian NIEs: Orchestrated latecomer development and its limits

The success of Korea, Taiwan, Singapore, and Hong Kong in electronics is remarkable. Korea's electronics industry has risen from a primitive state to the world's sixth largest producer of electronics, and even the third largest in consumer electronics and components. Taiwan is the seventh largest producer of electronics, thanks largely to its strong performance in office automation equipment. Singapore, ranking eighth on a global scale, owes most of its development to a lasting inflow of foreign direct investment. Hong Kong's position is somewhat less impressive, but the British colony still occupies eleventh position in overall electronics production. Each of the four countries approaches a 5 per cent world export share in electronics products. Singapore and Hong Kong have an important transit function, as reflected by the high import/export indicators relative to domestic production and consumption. The electronics industry is responsible for a fifth or more of total merchandise exports and as much as 45 per cent in the case of Singapore (Table 3A).

Table 3. **Indicators of electronics production and consumption for a selected number of NIEs, 1988 (in $ million)**

A. Production

Country	Production		Exports		Exports as a percentage of production	As a percentage of total merchandise exports
	Amount	%	Amount	%		
Korea	18 944	3.1%	13 613	4.9%	71.9%	24.1%
Taiwan	13 764	2.2%	11 961	4.3%	86.9%	21.5%
Singapore[a]	10 653	1.7%	13 231	4.7%	124.2%	45.0%
Hong Kong[a]	6 929	1.1%	13 689	4.9%	197.6%	23.8%
Malaysia	4 401	0.7%	4 590	1.6%	104.2%	48.9%
Thailand	1 733	0.3%	1 384	0.5%	79.9%	16.8%
Indonesia	1 011	0.2%	169	0.1%	16.7%	3.0%
Philippines	1 708	0.3%	1 321	0.5%	77.3%	30.1%
Brazil	9 520	1.5%	814	0.3%	8.6%	5.0%
India	4 038	0.7%	80	0.0%	2.0%	0.8%
World[b]	620 960	100%	279 444	100%	45.0%	11.7%
As a % of world	11.7%	-	21.8%	-	-	-

B. Consumption

Country	Electrical market[c]	Electrical imports	Imports as a percentage of market	TVs per thousand population	Telephones per thousand population
Korea	11 054	5 713	51.7%	329	209
Taiwan	7 132	6 419	90.0%	958	262
Singapore	5 300	7 878	148.6%	447	340
Hong Kong	4 565	11 147	244.2%	465	360
Malaysia	1 874	2 044	109.1%	95	68
Thailand	1 716	1 366	79.6%	62	17
Indonesia	1 417	575	40.6%	29	4
Philippines	599	263	43.9%	78	10
Brazil	9 692	984	10.2%	255	57
India	4 832	871	18.0%	12	5
World[b]	597 401	252 268	42.2%	-	-
As a % of world	8.1%	14.8%	-	-	-

a. High export ratio due to re-exports from nearby Malaysia c.q. China.
b. Excludes Africa, China, and parts of Latin America.
c. Inclusion of components can lead to double counting.

Source: Elsevier Advanced Technology, *Yearbook of World Electronics Data 1990,* Vols. I & II, and IBRD *World Development Report 1990*.

How have these NIEs been able to make substantial inroads into the oligopolistic group of electronics producers? All countries have followed heavily export-oriented growth strategies, based on low production costs, but that is not the whole story. For instance, the industrial past of some of the East Asian countries dates back much further than the 1960s. Japan colonised both Korea and Taiwan as part of its pre-war aspirations, and industrialised them according to its own model of state organisation, central banking, and *zaibatsu* conglomerates based on centralisation in Japan. Although this industrialisation model largely collapsed after the Second World War and although major parts of Korea's industrial base ended up in the Northern part, it is undeniable that this early industrialisation epoch provided a useful basis and direction for later development strategies[50].

Active government intervention has perhaps been the most important remnant of the previous industrialisation epoch. Governments of all first-tier Asian NIEs, except Hong Kong, have been highly interventionist. Measures range from subsidised and highly rationed credit as a way of directing investment into strategic industries to fiscal incentives with a similar objective[51]. An important element of these subsidies is that they are closely connected to targets for private firms. In Korea, the government has limited the number of new firms able to enter certain businesses, to exploit economies of scale. Another feature of the first-tier Asian NIEs is a strong commitment to education, with enrolment figures that are sometimes higher than in OECD countries[52].

A set of specific measures has been taken with respect to the electronics industry, dealing especially with acquiring foreign and generating indigenous technology. Singapore has relied extensively on foreign direct investment, while Korea and Taiwan have forged licensing, joint venture, and OEM agreements. Managers of foreign-owned establishments and joint ventures are often sent to parent companies' headquarters for training, while on-the-job training is also intensive. Samsung even offers overseas training for its personnel by joint venture partners. Besides, foreign-educated research personnel have been encouraged to return to their home countries. Several government-owned research institutes have been set up, both in Korea and in Taiwan, with the purpose of bringing in foreign technology and promoting domestic R&D efforts. The Korea Institute of Science and Technology was set up in 1966 as a multidisciplinary industrial research institute. Then, in 1976, the Korea Institute of Electronics Technology (KIET) was established; since renamed the Electronics and Telecommunications Research Institute (ETRI), it focuses on telephone exchanges and semiconductor research. Its Taiwanese counterpart, the Industrial Technology Research Institution (ITRI) is responsible for electronics research as well. Government assistance of this type was particularly effective in the 1970s, but is now less useful as many private firms have established their own R&D labs[53].

The effectiveness of these measures derives largely from the fact that they have been applied in such an orchestrated way. They have had a decisive impact on the availability of skilled labour, the development of capital markets, and the creation of advanced infrastructure, while directed government procurement policies boosted the domestic market. They have also affected firm strategy, structure, and rivalry, and influenced industries that are related to the electronics complex. As such, the first-tier Asian NIEs have constructed a position in which they could take advantage of the opportunities that were offered through the global expansion of the electronics market.

Despite the success of most of these strategies, the first-tier Asian NIEs have remained industrial and technological followers. The limited development, design and marketing capability of many of the NIE firms remains a constraint for a transition to more skill-intensive activities and industries. In Taiwan for instance, foreign invested electronics firms were found to be nearer to the technological frontier than domestic firms. They also employ a significantly higher proportion of technical personnel, invest more in R&D and in training of managers and engineers than home-grown Taiwanese firms[54]. The role of foreign technology remains critical for Taiwan as well as for the other first-tier Asian NIEs. It remains to be seen, however, whether technological leaders will be willing to license their technology to these NIEs in the future.

The follower status of the first-tier Asian NIEs becomes especially problematic as production costs soar through rising wages and inflation at a time that competition from second-tier NIEs is threatening. In addition, traditional export markets — for instance for Korean consumer products — are unlikely to grow as strongly as they did in the past. An increasingly hostile international trade regime imposes limits to export possibilities of the most successful NIEs, especially through proliferation of non-tariff barriers such as anti-dumping charges and voluntary export restraints (VERs). Bilateral restrictions on access to the United States and EC markets as faced by South Korea are a case in point. Other related roadblocks to further export success are the revaluation of the Korean and the Taiwanese currencies relative to the dollar, and the US Government decision to exclude first-tier Asian NIEs from the Generalised System of Preferences. Besides, many of the NIE firms face limited brand name recognition as a result of past OEM agreements.

A firm can adopt strategies that compete on cost or on differentiation. The danger for many firms from first-tier Asian NIEs is being trapped in the middle. Their confined technological potential is a handicap in competing with leading OECD-based firms on differentiation, while the rise of second-tier NIEs prevents them from competing solely on cost. The strategic direction of the first-tier Asian NIEs should be towards technological upgrading, increasing the value-added of the industry as a whole, and moving from consumer electronics to the industrial sector with a larger growth potential[55].

Second-tier Asian NIEs: A two-track development?

Second-tier Asian NIEs include Malaysia, Thailand, the Philippines, and Indonesia. These countries, all part of the ASEAN group, have a less impressive record in terms of electronics production and exports than the first-tier Asian NIEs, while their domestic markets are underdeveloped in terms of size and levels of sophistication. The numbers of televisions and telephones per 1 000 population show densities that are several orders of magnitude lower than in the first-tier Asian NIEs (see Table 3B). All countries depend for their production potential to a large degree on foreign direct investment. Until not too long ago, foreign direct investment in electronics came mainly from the United States, and poured typically into semiconductor assembly facilities in Malaysia and the Philippines. This situation has drastically changed recently. Japan is now the main source of foreign direct investment and invests not only in components but also in consumer products and office automation equipment.

The recent surge in ASEAN-bound foreign direct investment in the electronics industry has been directed primarily towards Thailand and Malaysia. By the end of 1989, 55 per cent of cumulative investment in Thailand's electronics industry came from Japan, only 17 per cent was Thai, while not more than 10 per cent came from the United States. First-tier Asian NIEs such as Singapore, Taiwan, and Hong Kong have started to invest in Thailand's electronics industry as well[56]. Detailed data on the foreign direct investment stock of Malaysian electronics (1987) still show the prevalence of US capital: US firms accounted for 32 per cent of fixed assets, while Japanese firms made up 23 per cent. Data on proposed electronics investments in Malaysia signal not only the increasing importance of Japan but also that of Taiwan: 42 per cent of the total proposed investment from 1985-1989 came from Japan, and 24 per cent from Taiwan.

Recent foreign direct investment in electronics has largely bypassed the Philippines. Severe political and economic instability in the 1980s has even caused the sell-off of some US semiconductor assembly facilities. Indonesia attracted very little direct investment in electronics until recently, but its prospects are better now that the investment climate has improved while costs remain low. Several Korean firms have invested in consumer electronics production.

Most of this new investment from Japan, Taiwan, and the other NIEs is related to increasing production costs at home. Low production costs and a favourable investment climate in Thailand and Malaysia encouraged the localisation of investments in these two ASEAN countries. An additional motive for investment was circumvention of trade barriers. Exporting from Thailand and Malaysia allows Japanese, Korean, and Taiwanese producers to bypass certain quotas and other non-tariff barriers that are imposed upon them by US and EC governments as part of bilateral trade agreements[57].

The main problem facing second-tier Asian NIEs such as Thailand and Malaysia is to what extent they will be able to absorb the foreign technology and foreign direct investment into the local economy. Both countries have a narrow industrial base. Thailand and Malaysia have local supplier networks that are weak compared to the magnitude and sophistication of foreign direct investment. Japanese companies, although slowly changing their policies, often prefer to bring own suppliers from Japan rather than rely on local ones. Besides, neither Thailand nor Malaysia has institutionalised mechanisms for absorbing foreign technologies. Unlike the first-tier Asian NIEs, the state has played a relatively passive role in developing the local R&D infrastructure. Government action has deliberately been focused on the creation of favourable FDI conditions.

The motives for foreign investors to locate their electronics production in Thailand or Malaysia have been largely related to relatively low cost levels, which can alter very rapidly. Relative exchange rates are prone to change, while the nature of trade conflicts can acquire new dimensions. The sudden increase of foreign direct investment, not only in electronics but also in other industries, into these small and 'shallow' economies has brought about an array of problems. Thailand especially suffers from an overburdened infrastructure including a clogged communications and transport system and sharply deteriorating environmental conditions affecting air and

water quality. There is a chronic shortage of skilled engineers, and wages are likely to rise as a consequence[58]. If Thailand and Malaysia cannot solve these problems in time, they may not be able to sustain high growth rates for long.

First-tier Latin American NIEs: The aftermath of excessive import substitution

The profile of Brazil, Mexico, and Argentina varies considerably from that of the Asian NIEs. Admittedly, their most dynamic industrial sectors often have oligopolistic structures, with heavy emphasis on state enterprises in Brazil and Mexico. But state regulation of trade and investment has been much less focused than in the Asian first-tier NIEs. Foreign direct investment has traditionally been an important means of technology transfer, but recent incoming flows have been very limited in Brazil and Argentina due to economic stagnation. In addition, there has been a substantial capital flight in these countries. The lack of investment — in physical as well as in human capital — has contributed to an overall deterioration of competitiveness. Moreover, both Brazil and Argentina have experienced hyper-inflation and highly overvalued currencies for quite a while, implying lost markets abroad. Mexico's economic performance, on the other hand, has improved considerably in recent years. The country has also been quite successful in attracting investment, especially from the United States.

Perhaps the largest difference between the Latin American and the Asian first-tier NIEs is that the former countries have been much more inward-oriented than the latter, with a long record of import-substitution strategies: only 8.6 per cent of Brazil's electronics production is exported, while not more than 10.2 per cent of its electronics consumption is imported (Table 3B). Such an extreme inward-looking orientation was sustainable with a large domestic market, but has become problematic during the last decade, a period of shrinking domestic markets due to economic crisis.

An important consequence of this inward-looking orientation has been firm entry into a number of new industry segments without regard to international competitiveness. The emphasis on the domestic market and the excessive entry of firms to serve that market has precluded many Brazilian electronics firms from reaping economies of scale. Brazilian firms usually adopt horizontal diversification as a growth strategy, combined with vertical integration that is encouraged by import restrictions and the lack of domestic suppliers. Accordingly, the Brazilian electronics industry is very diversified, ranging from semiconductors to televisions and from banking automation systems to public exchange systems. Both horizontal diversification and vertical integration have moved beyond the point of efficiency. Brazilian electronics producers have thus been forced to spread their resources among many competing activities. An insufficient degree of specialisation precludes many firms from accumulating the critical mass of technological assets that is necessary to improve product quality to levels required for exports.

Specialisation seems to be an unavoidable step after a decade in which the international competitiveness of the Brazilian electronics industry has declined. Brazil, like Mexico and Argentina, has been persuaded to liberalise its market and increase its exports in order to improve its trade balance and repay its debts. Liberalisation should itself foster greater specialisation.

The choice of promising products and product lines should be inspired by the relative strengths of the Brazilian economy in general. One of the more positive side-effects of the past import substitution policy is the proximity of users and producers in certain electronics segments. For instance, due to the size and characteristics of its banking system, Brazilian companies have constructed a potential competitiveness in banking automation, such as point-of-sales equipment, on which it may be able to capitalise in the future[59].

Second-tier Latin American NIEs: Forging user-producer links

Chile, Colombia, Uruguay, and Venezuela are marginal players on the world electronics scene. The Latin American second-tier NIEs are predominantly inward-looking, except Chile which has opened up its economy in the context of far-reaching trade liberalisation schemes. Their base for an inward-looking approach is very fragile, markets and production potential are more confined than in the larger neighbours of the continent, and export prospects for the electronics industry are even more limited. The electronics industry of the second-tier Latin American economies should therefore primarily be seen as an industrial service sector. The Uruguayan professional electronics industry, consisting of not more than fifteen enterprises, is engaged in the field of consultancy, maintenance, and marketing of foreign devices[60]. Colombia and Venezuela have tried to develop an electronics capital goods sector in connection with oil exploration and refining.

In the case of Venezuela, electronics production hardly existed until the mid 1970s. Exports were never a real option for electronics firms, due to the import substitution policy and the overvalued bolivar that reflected the oil exports. Nevertheless, recent developments have been more positive. Around a hundred professional electronics firms, mainly in telecommunication and instrumentation, were created in the 1980s. A strong demand for information techniques in the oil industry was partly responsible for this growth along with the development of qualified human resources and drastic bolivar devaluations. The professional electronics industry has not been directly engaged in exports, but has been animated by serving specific needs of other exporting sectors. Such a service role imposes certain requirements on the electronics industry — that it has to be highly competitive by itself. Gaining competitiveness is feasible through the creation of viable user-producer links, in this case with the oil extracting and refining industry. Such links have, as discussed in Section 2, the potential to generate innovations from which both the user and the producer can gain competitiveness. Venezuela's electronics industry demonstrates that competing through electronics can be a fruitful approach for countries whose technological capability and competitiveness lie primarily in other industries[61].

India: Balancing between self-reliance and liberalisation

India is much larger than the countries that have been discussed so far. It also belongs to the poorest of the world, and has therefore an internal market that remains restricted in size and especially in the level of sophistication. The electronics market of this quasi-continental economy is smaller than that of Hong Kong, whereas its total electronics output is smaller than that of Malaysia. The numbers of televisions and telephones per 1 000 inhabitants affirm that the Indian market for electronics products is very underdeveloped (Table 3A).

India has pursued for a long time a strong inward-oriented development strategy in which the electronics industry has played a major role. This strategy has been characterised by self-reliance, technological independence, state intervention, and protectionism. The electronics industry was among the most protected of all Indian industries, up until the 1970s. Although many electronics products were manufactured (like colour televisions, computers, and even indigenously developed ICs), the industry was very inefficient and produced outdated models at high costs. The country tried very hard to build its own technological capability, but was largely cut off from international developments, and hence far behind the technological frontier.

This technological obsolescence, combined with the slow growth of the Indian electronics industry, has led to a liberalisation tendency from the early 1980s on. Import duties were lowered, and large private firms were allowed to enter high-technology electronics production that used to be the exclusive domain of state-owned enterprises. In addition, importing of foreign technology was allowed and restrictions on the payment of royalties and technical fees were lifted. The liberalisation of the Indian electronics industry has led to an unprecedented growth of the industry, the attraction of a large number of manufacturers, resulting in intense competition, and lower prices. A wide range of consumer and related electronic products (including colour TVs, push-button telephones, and VCRs) as well as reasonably updated PCs are now produced in India. The nature of the industry has altered drastically. Import-dependency has increased rapidly, mainly because the production of new electronics products is limited to the assembly of imported kits. There has also been a significant drop in R&D activities, export results have been disappointing (except in software), and technology transfer from foreign direct investment is extremely limited[62].

The Indian case illustrates well the trade-offs between self-reliance and liberalisation. It also shows that a sudden policy shift from excessive and prolonged protection of the domestic industry towards trade liberalisation can leave scars. The weakening of a country's technological base can be an important drawback. Realisation of these consequences in India has led to a renewed introduction of import restrictions, albeit not as severe as those previously applied. Policy vacillation may itself be a serious drawback to the country's efforts to inject technological dynamism into its electronics industry.

V. IN CONCLUSION

Prospects for developing countries

Achieving international competitiveness in electronics is a major challenge for developing countries, now that competition has intensified in many product groups. Barriers to entry have proven to be particularly high in memory chips, mainframe computers, public switching equipment and high definition television. Competition has at times become so tough that even major players from the OECD area have left the arena. An array of barriers to entry, serving established market leaders, can dissuade NIE firms from engaging in a frontal conflict with industry leaders.

Competing in carefully selected niche markets is preferable to strategies with a broad target. The dynamism in electronics has provided many challenges that have not been taken up by market leaders, but niches that have successfully been filled up by NIE firms. Barriers to entry have proven to be surmountable in many consumer products, but also in certain niches of office automation equipment, communications, and software. Successes in TVs and VCRs, microwave ovens, personal computers and peripherals, home communications equipment, and ASIC design demonstrate the possibilities for late entry, given a sound manufacturing and skill base.

The windows of opportunity in the electronics industry have been beneficial to only a select group of NIEs. The prospects are less encouraging for many other developing countries. The electronics industry exemplifies the argument that constructed competitiveness is often cumulative, benefiting those countries that have already developed a skilled workforce, a good infrastructure, a viable home market, and a network of supplier and related firms.

An almost unavoidable conclusion, therefore, is that prospects for competing **in** electronics are very limited for those countries that have neither been able to build these determinants, nor been able to attract foreign direct investment. One reason why other countries should not try to copy Korea's success is that international markets (in this case for electronics) cannot absorb an unlimited number of competitors, each specialising in the same products, each competing on low costs. A fruitful development policy often reflects a nation's particular circumstances. This does not mean that electronics would have no future in other developing countries. It does mean, however, that it is risky to build a full-fledged development strategy around a sector that is highly restrictive and technologically difficult when the domestic industry is small and weak by comparison to its international counterparts.

The option of competing **through** electronics could be a more promising strategy for development. Electronic equipment forms an increasingly large part of capital goods, in the office as well as on the shopfloor. Although the effects of office automation on productivity levels have not been sufficiently analysed yet, the necessity of introducing automated manufacturing technologies has been proven. These technologies should not be seen only as a means of labour cost reduction or only of significance for high-labour cost countries. They have a range of attributes that are equally important for NIEs and developing countries: they induce higher product quality, reliability, flexibility, and increased speed-to-market — all important elements for competing on the global market. Widespread use of automated manufacturing

technology, however, is currently hindered by shortages of skills and software and by an outmoded organisation of firms and industries[63]. This constraint is applicable to OECD as well as to developing countries.

Some Latin American economies (like Venezuela, Uruguay, and possibly Brazil) are especially good candidates for a strategy that emphasises the export performance of other sectors with the support of the local electronics industry, through the creation of viable user-producer linkages. The professional electronics industry of several of these countries has not reached a world class status yet, which is partly a result of extended import-substitution programmes. Several NIEs would therefore be better off facing the reality that their users of electronics are often more significant players on the world scene than their producers of electronics. Such an attitude could clear the path for an approach that regards the electronics industry as an industrial service sector. These linkages have the potential to generate innovations, from which both the user and the producer can gain competitiveness. Learning-by-making and learning-by-using as complementary processes can create synergies. The effect of such a strategy is twofold. The competitiveness of the electronics users increases through the installation of custom-made capital goods. The local electronics producers benefit as well, since they can build design and fabrication capabilities that could lead in the long run to international competitiveness within a specific niche.

The user-producer approach has been investigated for a few Latin American economies (Brazil, Venezuela, Uruguay). Expansion of the user-producer approach is recommended, although only to countries with (at least) a minimally developed professional electronics sector. Such a threshold requirement on the part of the electronics industry, more in terms of sophistication than in terms of size, is essential since only then can it foster the competitiveness of the exporting sector. The importance of a local professional electronics sector is underlined by the increasing difficulty to master the use of new information technologies (such as automated manufacturing technology) without nearby suppliers. Electronics technology users also need at least basic computer literacy. These prerequisites on the part of both electronics users and electronics producers imply that the user-producer approach has its limits for those developing economies that do not fulfil these criteria.

How to catch up technologically?

One crucial question pre-occupies almost every developing country that wants to develop its electronics industry: how to acquire technology? Two broad pathways towards technology acquisition have been discussed: generating indigenous technology and access to foreign technology. The experience from the electronics industry has shown that both pathways reinforce each other; a choice for either one alone is dangerous for any country, even for technological leaders from the OECD area. Brazil and especially India have made a choice in the past for technological independence, but the result has been an industry that could not keep up with the technological frontier, and very unlikely to become internationally competitive. Access to foreign technology is therefore critical, but not enough in itself. Thailand and Malaysia are countries that have benefited from the inflow of technology through foreign direct investment. Under such circumstances, becoming less aggressive about building indigenous technological capability is tempting but nevertheless equally risky.

A major argument is that developing countries that have benefited from foreign direct investment cannot afford to be complacent about the construction of their own competitiveness. The most successful latecomer countries, Korea and Taiwan, have tread both pathways towards technology acquisition simultaneously, with a successful record in building competitiveness in electronics as a result.

Foreign technology can be acquired through several means, such as foreign direct investment, OEM agreements, import of capital goods and human resources, technology licensing, co-operative agreements, and through the acquisition of innovative start-up companies. Although some of these means of technology transfer have appeared to be more effective than others, they should all be considered *a priori* by policy makers that are pursuing an active technology acquisition strategy. They will therefore be briefly reviewed.

Foreign direct investment can be an important channel for technology transfer, but the positive effects do not always come automatically. Local personnel become familiar with the operation of an (assembly) manufacturing plant, but the formation of skilled personnel only happens gradually and with effort. Ideally, skilled personnel leave the foreign establishment and form their own spin-off firms. Another possible spill-over of foreign direct investment is the opportunity to build a local subcontracting network around the foreign plant. Yet, the experience of NIEs such as Thailand and Malaysia shows that these spin-offs do not always take place, since their indigenous capability is at times insufficient to absorb the foreign technology. Measures to reduce the gap between the foreign and the domestic sectors are called for. Agreements between foreign investors and host countries can take these issues into consideration, for instance by eliciting commitments from foreign firms to source locally and train local personnel.

Original equipment manufacture has proven to be a successful element of catching-up strategies. The cases of Korea and Taiwan show that production of electronics equipment under the name of other companies can be a way to break into world markets. On the one hand, it is in the customer's interest to give detailed technical specifications and technical assistance to the OEM supplier, since a firm needs a certain technological level to qualify. On the other hand, the relationship enables the supplier to rely on the marketing and distribution network of the customer, thus economising on its own marketing and distribution expenses. The experience of Korean and Taiwanese firms, however, demonstrates that OEM agreements make own brand-name (OBN) sales difficult because of these missing distribution networks and a lack of customer recognition. By continuing to rely on OEM sales, firms forfeit the higher margins associated with OBN sales.

It was mentioned before that the import of capital goods can be helpful in competing through electronics. Its utility as a means of technology transfer, however, remains limited, since much technology is disembodied. Technology can often be found in 'the brains of people'[64]. The central role that people play in transferring and disseminating technology has been deemed as "perhaps the most important point emerging from the history of the computer industry"[65]. Importing skilled personnel is therefore often more effective than importing capital goods. The recruitment of foreign personnel can have fruitful results in the short term, but attracting own nationals that are abroad might be more important in the long run, since they are much more likely to remain part of the domestic labour force. Sending people overseas for

postgraduate training, especially to places like Silicon Valley, can be very effective. Depending on the knowledge that is required, both governments and firms can offer support for enrolment in foreign universities or training institutes. Scholarships for studying abroad can be an effective means of technology transfer, if the return of the students in question can be secured.

Technology licensing and co-operative agreements are different forms of technology transfer, but the distinction between the two is sometimes hard to make. Leading companies in the electronics industry are usually quite willing to license next-to-cutting-edge technology, so that they can increase their own returns on R&D investments. Licensing is important for firms and countries that are still behind the technological frontier. But licensing has its limitations for those who are positioned in more advanced stages of a catching-up strategy, since leading firms are reluctant to license cutting-edge technology that is necessary for international competition. Licensing has therefore increasingly become part of a broader agreement including complementary assets such as access to other technologies, access to markets or access to production facilities. Interfirm co-operative agreements with a licensing component have been actively pursued by firms from first-tier Asian NIEs. Technologies that would never have been licensed on their own have thus become available to NIE firms.

All interfirm agreements have to be negotiated, and being a strong partner is therefore a definite advantage. Firms from the first-tier Asian NIEs have been able to set up a substantial number of co-operative agreements with leading electronics companies that are in turn interested access to low cost production bases and in access to the growing markets of the first-tier Asian NIEs. Strategic partnerships that bundle the R&D efforts of two or more companies go still one step further. Some of the largest companies from Korea and Taiwan have been able to set up such partnerships (mainly in semiconductors) with leading Japanese and US companies. In conclusion, co-operative agreements can be an effective means of technology transfer for first-tier NIEs that have substantial complementary assets. Firms from other developing countries usually lack these assets.

Acquisition of innovative start-up companies by NIE firms is a relatively new phenomenon, made possible by the cash richness of some NIE firms, notably the Korean *chaebol*. Acquisition of innovative start-ups, usually US firms, can be very costly, but can make cutting-edge technology as well as forthcoming innovations available to the parent company. Yet, it will remain to be seen whether the investor will be able to make effective use of this new technology[66].

A crucial policy conclusion is that several means of technology transfer, such as original equipment manufacture and co-operative agreements, are not feasible for countries that do not have a pre-existing technological capability. But even the effectiveness of foreign direct investment and acquisition of innovative start-up companies remains very limited if the host country lacks a foundation consisting of basic skills. The importance of indigenous technological capability building is hereby underlined once more.

How to build such a technological capability? Whereas acquisition of foreign technology is mostly an interfirm concern in which governments play at most a supportive role, this is not the case for technological capability building. A wide range

of instruments can be used for building an educational as well as a communication infrastructure, next to implementing an effective science and technology policy. Each of these elements, all advanced factors of production, is a critical part of a strategy that is directed towards the construction of competitiveness.

Education and training of the workforce are important means of creating competitiveness. As a recent study has shown, there is an explicit link between education of the workforce, the ability to achieve new high performance forms of work organisation, and productivity growth. Establishing high educational standards and motivating students to comply to these standards are ambitious policy objectives[67]. The relationship between competitiveness and education is demonstrated by the first-tier Asian NIEs, that have made an enormous commitment towards education, with very high enrolment figures as a consequence. Whereas education has a universal importance, training is much more specific and therefore pivotal in creating competitiveness in a sector such as electronics. New technologies require new skills. For instance, the adoption of automated manufacturing technologies requires very specific skills for repair and maintenance. But even countries which are engaged in the assembly of consumer electronics and components find that they need more highly skilled labour in order to supervise, maintain, repair, and troubleshoot sophisticated automated production and testing equipment. Both formal and on-the-job training are required, and close linkages between educational institutes and the electronics industry therefore deserve special attention.

Several NIEs with a strong commitment towards indigenous technological capability building (Korea, Taiwan, Brazil, India) have or have had government laboratories focused on the electronics industry. The success record of these laboratories is mixed. Such laboratories can be a catalyst for domestic R&D efforts in a certain developmental stage of the industry. They can grow out of contract work for private industry, as is the case with Taiwan's ITRI. Yet, the overall role of government laboratories remains rather limited. Certainly, the fact that development of certain products is not picked up by the private sector can be due to lack of foresight or lack of resources by NIE firms. But it is equally likely that the market considers the prospects for such product development less than rosy. As recent history has shown, government laboratories often lack this foresight since they are insensitive to market signals. Their impact can even be negative when they are isolated from developments in the private sector, because they draw from a small pool of specialised and skilled personnel on which the private sector depends as well. This problem is likely to become more severe since the shortage of electronics engineers and technicians in certain countries is expected to worsen.

Infrastructure policy is the third pillar of a government policy towards technological capability building. Sufficient road and rail transport are absolute prerequisites for almost every industry. Air links to major markets are also critical in the case of electronics. An advanced communication network is also important for electronics producers and users, as is a reliable electricity supply. Reliable data communication is a weak point for many developing countries. An improvement of telecommunication facilities, following the example of the first-tier Asian NIEs, is therefore highly recommended.

Building a technological capability is crucial. It implies that technology can be generated and foreign technology more easily absorbed. It also implies that foreign technology can be more easily lured, since foreign investors are especially attracted by such factors as a skilled labour force and a decent communication infrastructure. In other words, the dichotomy between foreign technology acquisition and indigenous development is often a false one. Latecomer industrialisers that want to reach the technological frontier should integrate both means of technology acquisition.

Strengthening industrial structures and enhancing domestic rivalry

Latecomer industrialisation in electronics has provided a variety of examples of widely diverging industry structures. From vertical disintegration in Taiwan to vertical integration in Korea and from horizontal diversification in Brazil to specialisation in Malaysia. No structure is obviously superior in all circumstances. Both Korea and Taiwan have been successful in electronics, although they have widely diverging industrial structures. Taiwanese firms, usually small in size, have proven to be flexible, which is a definite advantage in a dynamic industry like electronics. Korean firms, notably the four leading *chaebol*, lack this advantage but benefit from their size when it comes to giant investments, for instance in semiconductor development. Taiwan's industrial structure allows firms to launch electronics products with lower entry barriers ahead of Korean firms, who, however, often narrow the gap over time and eventually make equal or superior products. This does not mean that the Korean firm model can or should be replicated: too much depends on established economic, institutional, and political structures that differ from country to country[68].

A stronger recommendation can be made about the specialisation-diversification trade-off. International competition in a field such as electronics makes specialisation a preferable strategy. Companies need to make a serious commitment if they want to reach the technological frontier in any of the segments of the industry. It is very rare for NIE firms, as it is for OECD-based firms, to achieve such a position in more than a few related product groups. Specialisation is also desirable in the context of competing through electronics, where specific (exporting) users of professional electronics are supported by a local electronics industry that can focus on developing systems for specialised applications.

Whatever the exact industrial structure, successful latecomer countries (Japan, Korea, and Taiwan) all have fostered the idea of domestic rivalry. Unlike some other countries, they have not opted for picking a single national champion, but given room to the development of a competitive electronics sector, consisting of at least a handful of well-matched firms, facing each other in the domestic market. In this way, government tools can be much more selective in supporting the local electronics industry; one is not 'locked in' to the support of a single national champion.

The importance of the domestic market as a determinant of competitiveness should be underlined once more, even for export-oriented economies. The domestic market is more than a springboard or a test ground for new products. Domestic users are equally important as partners in the innovation process. A sophisticated home market is therefore more important than a large home market. Governments can help

upgrade the domestic market, through procurement policies or through assisting in the diffusion of advanced electronics, as in the case of automated manufacturing technologies.

Examining trade and investment relations

Latecomer industrialisers that seek the development of their electronics industry have experimented with a wide range of trade policies, varying from severe protectionism to extreme liberalisation. A few lessons can be drawn from this rich experience.

Probably the most important lesson is that international competitiveness in the electronics industry cannot be obtained through exclusively inward-looking strategies. Protectionist policies that prohibit competition from abroad can lead to the inefficient production of outdated products at high costs. An outward-looking, export-oriented approach has been much more successful, especially for those NIEs with limited domestic markets. Exports allow for economies of scale, while unrestricted imports provide a litmus test of domestic competitiveness. Some countries, especially Hong Kong and to a certain extent Singapore, have pursued an open economy, with virtually no restrictions on international trade and investment. Some of the larger Asian NIEs have pursued active export promotion strategies with a more interventionist character. Whatever the strategy, these exporters have a crucial interest in an international trade environment with minimal trade barriers.

How should NIEs react when such a free trade environment is threatened, as is increasingly the case in electronics? This question is particularly relevant for the most successful exporters (notably Korea and Taiwan) that have run up against the limits of their own success. Moving production capacity to the target markets, following the Japanese example, is becoming a virtual necessity to maintain market share in these crucial markets. Both Korean and Taiwanese firms have already set up manufacturing facilities in the United States and the EC, and this trend is likely to continue. Upgrading existing product lines towards higher value-added segments, often away from consumer electronics, is equally necessary[69]. Establishing co-operative agreements with major players in target markets can be helpful in this process. International marketing agreements have become common practice by now. Korean and Taiwanese electronics firms, dominating their own domestic markets, possess a valuable asset. Access to these domestic channels for foreign products could be swapped for access to established channels within major OECD markets. Electronics companies and governments in major OECD markets should realise that many NIEs are future growth markets, and that the price that has to be paid for protectionism in terms of lost revenues could be high in the near future.

Yet, a totally liberalised trade environment has its drawbacks for certain other NIEs. The experience from Brazil and India shows that a shock-like liberalisation of a protected industry can be harmful for local innovative capacity. Drastic trade liberalisation can make the industrial base more shallow, with a bias towards assembly or screwdriver plants that simply import all components and parts. An alluring analogy can drive this point home: "No domestic animal is expected to survive if suddenly let loose in the jungle, and it would not be the fault of the animal but of the domesticator"[70]. Infant industry protection arguments should not be rejected out of hand. The problem is that it is very easy to keep trade barriers high when the child

grows up. The overall weak performance of European computer firms is illustrative: long-lasting protection of national champions, shielded from foreign competition, has not led to the creation of strong global players. Yet, a properly designed infant industry protection strategy can exercise pressure on firms to innovate and bring their products to international standards. Such protection should be phased out over a predetermined time span, for instance over ten years, so that domestic companies can prepare for a fair battle.

Constructing competitiveness in electronics requires a long-term view, to be measured in decades rather than in years. A supportive government is a definite advantage if not a prerequisite for a successful initiation and progression of this process. The precise role of governments in such a long-term development is not entirely disconnected from political choices. However, the fact that governments of many OECD countries have decided to support their electronics industries has a bearing on the strategies of the NIEs as well. The United States, Japan, and Europe support their electronics industries in more or less direct ways, for example through protectionist measures, through the support of R&D efforts, and through spin-offs from the defence industry.

OECD countries do not always provide examples of effective government intervention. In some countries, government support has been almost equivalent to pouring subsidies into 'national champions', whose international competitiveness is still weak. Moreover, military contracts are major sources of revenue for electronics firms in several countries. With cuts in military spending, firms face the difficult task of adapting to competition in commercial markets. The argument is often made that, in late-industrialising countries, the state intervenes deliberately to distort relative prices in order to stimulate economic activity. Where subsidies are employed to support the electronics industry, they need to be linked to performance requirements on the part of private firms, as has happened e.g. in Korea and Taiwan[71]. Overall, it is hard to deny that NIEs with effective government support have been more successful in constructing competitiveness than NIEs where the role of the state is considered to be less effective (for example some Latin American economies). Building a nation's competitiveness in electronics has turned out to be most effective in the framework of a range of co-ordinated or orchestrated policies, including trade, industry, science and technology, and educational policies.

NOTES

1. C. Perez (1990), "Electronics and Development in Venezuela: A User-oriented Strategy and its Policy Implications", *Technical Paper No. 25*, Paris, OECD Development Centre, p. 13.

2. See "Tricks of the Trade", *The Economist*, 30 March 1991, p. 6.

3. This definition comes from the Report of the President's Commission on Industrial Competitiveness (1985), *Global Competition: The New Reality*, and has been used by the OECD Technology/Economy Programme (1990), *Draft Background Report*, Chapter 10 "Technology and Competitiveness." The reference to "free and fair market conditions" remains debatable.

4. Competitiveness and comparative advantage are often confused. The notion of (static) comparative advantage lacks those attributes that make the concept of competitiveness so valuable for our purpose. Comparative advantage is not built on the level of the firm but built on the national level. In addition, comparative advantage is based on an idea of factor endowments in which the term technology is conceptualised in a very different way. Furthermore, comparative advantage theory assumes away non-market interactions that have become an important element of present day competition. The application of the theory of comparative advantage is especially problematic in the case of modern technology-intensive industries as electronics, and will therefore be left out in this paper.

5. M. Porter (1990), *The Competitive Advantage of Nations*, London, MacMillan, p. 40.

6. D. Ernst and D. O'Connor (1992), *Competing in the Electronics Industry — The Experience of Newly Industrialising Economies*, Ch. I, p. 4.

7. Kline S.J. and N. Rosenberg (1986), "An Overview of Innovation", in National Academy of Engineering, *The Positive Sum Strategy: Harnessing Technology for Economic Growth*, Washington, D.C., The National Academy Press, p. 299.

8. C. Perez and L. Soete (1988), "Catching up in technology: Entry barriers and windows of opportunity", in Dosi *et al.* (ed.), *Technical Change and Economic Theory*, London/New York, Pinter, p. 460.

9. *Ibid*., p. 477.

10. S. Lall (1990), *Building Industrial Competitiveness in Developing Countries*, Paris, OECD Development Centre Study.

11. D. Ernst and D. O'Connor (1989), *Technology and Global Competition: The Challenge or Newly Industrialising Economies*, p. 40.

12. S. Ostry (1990), "Exploring the Policy Options for the 1990s", paper prepared for the OECD Conference on *Support Policies for Strategic Industries: Systemic Risks and Emerging Issues*, Paris, 30 October 1990, pp. 3-4.

13. D. Ernst and D. O'Connor (1989), *op. cit.*, p. 26.

14. "Science, Technology, and Competitiveness", *STI Review*, Autumn 1986, p. 110.

15. OECD TEP Conference on Technology and Competitiveness, Paris, 25-27 June 1990.

16. D. Ernst and D. O'Connor (1992), *op. cit*., Ch. IV.

17. South Africa is an exception, but this country has not been included in the analysis.

18. OECD Technology/Economy Programme (TEP) (1990), *Draft Background Report*, General Introduction, p. 8.

19. M. Porter (1990), *The Competitive Advantage of Nations*, London, MacMillan, p. 8.

20. D. Ernst and D. O'Connor (1992), *op. cit*., Ch. II.4.

21. S. Lall (1990), *Building Industrial Competitiveness in Developing Countries*, Paris, OECD Development Centre Study, p. 18.

22. D. Ernst and D. O'Connor (1989), *op. cit.*, p. 21.

23. See D. Ernst and D. O'Connor (1992), *op. cit.*, Ch. I, for a more far-reaching discussion of the barriers to entry discussion.

24. This section is, unless otherwise indicated, mainly based on D. Ernst and D. O'Connor (1992), *op. cit.*, Ch. III.1.

25. If not otherwise indicated, the following figures on market size are based on Elsevier Advanced Technology (1990), *Yearbook of World Electronics Markets*.

26. "Recent Developments in the Consumer Electronics Industry", *STI Review*, April 1989, pp. 113-128.

27. "Executive Briefing on HDTV", *Electronics*, October 1990, pp. 48-58.

28. Quote from OECD Technology/Economy Programme (1990), *Draft Background Report*, Ch. 2, "Technological Innovation: Some Definitions and Building Blocks", p. 30.

29. This section is, unless otherwise indicated, mainly based on D. Ernst and D. O'Connor (1992), *op. cit.*, Ch. I and III 2/3.

30. K. Flamm (1988), *Creating the Computer*, Washington, D.C., The Brookings Institution, p. 5.

31. This section is, unless otherwise indicated, mainly based on D. Ernst and D. O'Connor (1992), *op. cit.*, Ch. III.4.

32. This section is, unless otherwise indicated, mainly based on D. Ernst and D. O'Connor (1992), *op. cit.*, Ch. III.5.

33. Merchant semiconductor sales do not include captive production, in which US companies such as IBM and DEC prevail. From "Inside the top 50 worldwide chip companies", in *Electronics Business*, 8 April 1991, p. 38-39.

34. *Electronic World News*, 19 November 1990, p. 1.

35. Dataquest information, cited in *The Economist*, 14 July 1990, p. 78.

36. The ASIC discussion is based on M. Hobday's (forthcoming), "The Diffusion of Application Specific Integrated Circuits (ASICs)", part II of D. Ernst (ed.), *Technology Trends in Advanced Electronics — Implications for NIEs*, Paris, OECD Development Centre Study.

37. D. Ernst and D. O'Connor (1992), *op. cit.*, Ch. III.5.

38. This discussion is based on R. Schware's (forthcoming), "Trends in the World Software Industry and in Software Engineering", part I of D. Ernst (ed.), *Technology Trends in Advanced Electronics — Implications for NIEs*, Paris, OECD Development Centre Study.

39. The 1996 estimate comes from Watanabe (1989, p. 5) as cited in R. Schware.

40. D. Ernst and D. O'Connor (1992), *op. cit.*, Ch. II.

41. See for a more detailed treatment of this issue C. Correa's "The Legal Protection of Software: Implications for Latecomer Strategies in Newly Industrialising Economies (NIEs) and Middle-Income Economies (MIEs)", *Technical Paper No. 26*, Paris, OECD Development Centre.

42. OECD Technology/Economy Programme (1990), *Draft Background Report*, Chapter I, "Technology and Economic Growth".

43. L. Soete (1985), "International Diffusion of Technology, Industrial Development and Technological Leapfrogging", in *World Development*, Vol. 13, No. 3, p. 409-422.

44. C. Antonelli (1992), *The International Diffusion of Advanced Telecommunications: Opportunities for Developing Countries*, Paris, OECD Development Centre Study.

45. OECD Technology/Economy Programme (1990), *Background Report*, Ch. II.

46. OECD (1991), *Managing Manpower for Advanced Manufacturing Technology*, Paris, OECD.

47. Edquist and Jacobsson 1988, cited in D. Ernst and D. O'Connor (1992), *op. cit.*, Ch. II.

48. OECD Technology/Economy Programme (1990), *Background Report*, Ch. II.

49. See for an independent treatment of China R. Conroy's *Technological Change and Industrial Development in China*, Paris, OECD Development Centre Study, 1992.

50. B. Cumings (1987), "The Origins and Development of the Northeast Asian Political Economy: Industrial Sectors, Product Cycles, and Political Consequences", Chapter II in F. Deyo (ed.), *The Political Economy of The New Asian Industrialism*, Ithaca, Cornell University Press.

51. OECD Technology/Economy Programme (TEP) (1990), *Draft Background Report*, Chapter 11 "New Technology, Latecomer Industrialisation and Development Today", p. 5.

52. IBRD, *World Development Report 1990*, p. 234.

53. M. Bloom (1992), *Technological Change and the Electronics Industry: Perspectives and Policy Options for the Republic of Korea*, Paris, OECD Development Centre Study, p. 14.

54. Gee. San (1990), "The Status and an Evaluation of the Electronics Industry in Taiwan", *Technical Paper No. 29*, Paris, OECD Development Centre.

55. See Jun Y. and S. Kim (1989), *Structure and Strategy in the Korean Electronics Industry*, for specific policy recommendations for the Korean case.

56. Figures from the Thai Board of Investment and the Malaysian Industrial Development Authority, cited in D. Ernst and D. O'Connor (1992), *op. cit.*, Ch. II.

57. Figures from the Malaysian Industrial Development Authority, cited in D. Ernst and D. O'Connor (1992), *op. cit.*, Ch. II.

58. "Can booming Thailand survive its success?", *Electronic Business*, 7 January 1991, pp. 61-64.

59. C. Frischtak (1990), "Specialization, Technical Change and Competitiveness in the Brazilian Electronics Industry", *Technical Paper No. 27*, Paris, OECD Development Centre.

60. Sutz, J. (1989), *Electronics and Development in a Small Country — The Uruguayan Case*, Paris, OECD Development Centre Background Paper, p. 18.

61. C. Perez (1990), "Electronics and Development in Venezuela, A User-oriented Strategy and its Policy Implications", *Technical Paper No. 25*, Paris, OECD Development Centre.

62. G. Alam (1990), "The Indian Electronics Industry: Current Status, Perspectives and Policy Options", *Technical Paper No. 30*, Paris, OECD Development Centre.

63. See for a detailed treatment of this problem OECD (1991), *Managing Manpower for Advanced Manufacturing Technology*, Paris, OECD.

64. D. Ernst and D. O'Connor (1989), *op. cit.*, Paris, OECD Development Centre Study, p. 20.

65. K. Flamm (1989), "The Computer Industry in Industrialized Economies: Lessons for the Newly Industrializing", *Industry Series Paper No. 8*, The World Bank Industry and Energy Department, p. 28.

66. This section is largely based on D. Ernst and D. O'Connor (1992), *op. cit.*, Ch. II.4.

67. The Commission on the Skills of the American Workforce (1990), *America's Choice: High Skills or Low Wages*!, Rochester, NY, National Center on Education and the Economy, Executive Summary.

68. A. Mody (1989), "Institutions and Dynamic Comparative Advantage: Electronics Industry in South Korea and Taiwan", *Industry Series Paper No. 9*, The World Bank Industry and Energy Department.

69. Jun Y. and S. Kim (1989), *The Korean Electronics Industry — Current Status, Perspectives and Policy Options*, Paris, OECD Development Centre Background Paper.

70. C. Perez (1990), "Electronics and Development in Venezuela: A User-oriented Strategy and its Policy Implications", *Technical Paper No. 25*, Paris, OECD Development Centre, p. 47.

71. A.H. Amsden (1989), *Asia's Next Giant: South Korea and Late Industrialisation*, New York/Oxford, Oxford University Press.

FURTHER READING

OECD Development Centre Studies

BLOOM, Martin (1992), *Technological Change and the Electronics Industry: Perspectives and Policy Options for the Republic of Korea,* OECD Development Centre, Paris.

CONROY, Richard (1992), *Technological Change and Industrial Development in China,* OECD Development Centre, Paris.

ERNST, Dieter and David O'CONNOR (1989), *Technology and Global Competition, The Challenge for Newly Industrialising Economies,* OECD Development Centre, Paris, 153 pages.

ERNST, Dieter and David O'CONNOR (1992), *Competing in the Electronics Industry — The Experience of Newly Industrialising Economies,* OECD Development Centre, Paris.

LALL, Sanjaya (1990), *Building Industrial Competitiveness in Developing Countries,* OECD Development Centre, Paris, 74 pages.

OECD Development Centre Technical Papers

ALAM, Ghayur (1990), "The Indian Electronics Industry: Current Status, Perspectives and Policy Options", *Technical Paper No. 30,* OECD Development Centre, Paris.

CORREA, Carlos Maria (1990), "The Legal Protection of Software: Implications for Latecomer Strategies in Newly Industrialising Economies (NIEs) and Middle-Income Economies (MIEs)", *Technical Paper No. 26,* OECD Development Centre, Paris.

FRISCHTAK, Claudio R. (1990), "Specialization, Technical Change and Competitiveness in the Brazilian Electronics Industry", *Technical Paper No. 27,* OECD Development Centre, Paris.

PEREZ, Carlota (1990), "Electronics and Development in Venezuela, A User-oriented Strategy and its Policy Implications", *Technical Paper No. 25,* OECD Development Centre, Paris.

SAN, Gee (1990), "The Status and Evaluation of the Electronics Industry in Taiwan", *Technical Paper No. 29*, OECD Development Centre, Paris.

YAMADA, Bundo (1990), "Internationalization Strategies of Japanese Electronics Companies: Implications for Asian Newly Industrializing Economies (NIEs)", *Technical Paper No. 28,* OECD Development Centre, Paris.

External Publications

OECD (1992), "New Technology, Latecomer Industrialisation and Development Today", Chapter 11 of the Background Report *Technology and the Economy: The Key Relationships,* resulting from the Technology Economy Programme (TEP) commissioned by the Council at Ministerial Level in 1988.

VICKERY, Graham (1991), "The European Experience in Advanced Electronics — Lessons from the European Experience", in *STI Review,* No. 9.

HOBDAY, Michael (1991), "Semiconductor Technology and the Newly Industrialising Countries: The Diffusion of ASICs (Application Specific Integrated Circuits)", in *World Development,* Vol. 19, No. 4, pp. 375-397.