MICROELECTRONICS, TNCs AND DEVELOPMENT*†

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* A review article of **The U.S. Microelectronics Industry: Technical Change, Industry Growth and Social Impact,** *by Nico Hazewindus, with John Tooker* (New York, Pergamon Press, 1982).

Robots in Manufacturing: Key to International Competitiveness, *by Jack Baranson* (Maryland, Lomond Publications, 1983).

Computer-Aided Design: Electronics, Comparative Advantage and Development. A UNIDO Study, *by Raphael Kaplinsky* (London, Frances Pinter, 1982).

Technological Trends and Challenges in Electronics, *by S. Jacobsson and J. Sigurdson, eds.* (University of Lund, Research Policy Institute, 1983).

The Global Race in Microelectronics: Innovation and Corporate Strategies in a Period of Crisis, *by Dieter Ernst* (Frankfurt, Campus, 1983).

Throughout history, new technologies have often initially been seductive and have created tendencies to mystify their potential benefits and implications. This is no different in the case of microelectronics and associated technologies. Yet it is precisely this trend towards mystification that makes an objective description of the technology all the more imperative.

MICROELECTRONICS

In this regard, the study by Hazewindus is especially noteworthy. Hazewindus is an insider with respect to microelectronics since he is with N.V. Philips, which holds the largest market share in semiconductors in Western Europe held by a European firm. It provides an excellent, easily understood and comprehensive overview of microelectronics technology, its major areas of application, the integrated-circuits industry and expected future trends for this industry. Special attention is also given to the technology base of the United States integrated-circuits industry, human resources and employment problems associated with the technology and the types of policies that federal and state agencies have adopted with respect to microelectronics.

For the lay reader wishing to gain a fairly comprehensive factual understanding of this technology, Hazewindus's book is invaluable, even if one does not agree with its underlying pro-technology bias.

† Reprinted from the *CTC Reporter,* a publication prepared by the United Nations Centre on Transnational Corporations.

The refreshing feature of this book is that there is no implicit or explicit attempt made to mystify the technology or to legitimise it. The facts are stated as viewed by an insider in the industry and there is no attempt at grand theorising. Hazewindus's study provides a very useful overview of the major United States, Japanese and Western European firms involved in the intergrated-circuits industry. He draws attention to the need to distinguish between the "merchant" industry and the "captive" industry, the latter being those firms which manufacture for their own internal use, and provides brief profiles of the major firms in each category. The point is clearly made that the manufacture and sale of integrated circuits is a global enterprise, although the major production centres are the United States, Western Europe, Japan and, to a much lesser extent, some South-East Asian countries. Nearly 60 per cent of world production of the merchant industry is accounted for by the United States, and even in Western Europe, a major portion is derived from subsidiaries of U.S. companies.

As may be expected, many of the major actors in this industry are TNCs: IBM, Siemens, United Technologies, NEC, Gould, Honeywell, to name a few. Hazewindus's report both highlights the significant role of TNCs in this industry and provides an excellent overview of the more prominent companies. Though there is no attempt made to analyse how this TNC dominance relates to the broader issue of the transnationalisation of production and the changing role of TNCs in this regard, that does not detract from the value of the book.

There is, however, a brief but incisive discussion about how the structure of the industry has changed over the past ten years, how many Silicon Valley firms have been the targets of takeovers by major corporations (both from the United States and Western Europe) and what this may mean for innovative activity in this technology. The author notes (p. 84):

> Some observers believe that firms that now form part of larger companies will undertake a shift from a technological, innovative focus to a more traditional business orientation. On the other hand, the large multinational companies which have acquired Silicon Valley firms may be in a better position to absorb temporary losses while pursuing long-term goals of increasing market share and product positioning.

The book also discusses the difference between the United States and Western European industry, the latter being characterised by a number of large vertically-integrated electronics TNCs such as Philips and Siemens, and traditionally being more oriented towards consumer electronics and telecommunications than towards data processing.

The industry is weak in such areas as metal-oxide-silicon (MOS) memory and microprocessors and hence it is not surprising that many Western European Governments have undertaken microelectronics-support programmes to compensate for such weaknesses.

An important section in the book deals with the technology base of the United States integrated-circuits industry and the increasingly critical role of advanced research and development. Although at present much of the research and development in the field is undertaken by the industry itself, several major universities have initiated programmes of research and development in specific areas; for example, MIT and Stanford University intend to secure a leading position in very large scale integration science. What is more interesting, though, is the increasingly closer ties between industrial firms and universities in this technology, and the possibility that the integrated-circuits industry may become a major source of funding for university research and development. With TNCs being the major actors in the integrated-circuits industry, this trend could herald a further incorporation and integration of academic research into TNC activities, with all the ramifications this has for the rate and direction of technological progress, and the access to this technology by developing countries.

ROBOTS

Baranson's book on robotics and manufacturing is similar in coverage and style to that by Hazewindus, with the focus on Automated Manufacturing Equipment and Systems (AMES). It is also a good source of information on the technology and the associated industry. One difference is that there is a greater preoccupation with the decline in United States competitiveness internationally, and a substantial portion of the book is devoted to country studies of the relevant policies of the United States, Japan and Western Europe with respect to this technology. Baranson's main argument is that "future competitiveness in world industrial markets will depend, to a significant degree, upon a nation's ability and determination to develop and install these new industrial systems as rapidly and extensively as world market competitive conditions change and domestic (economic or political) conditions encourage or allow" (p. 3). In this regard, Baranson points out that Japan is far ahead of the United States in the production and installation of robot systems and that a major factor is that the demand for these systems is much stronger and more extensive there than in the United States.

The book contains a concise overview of the characteristics and implications of AMES; it is perfectly tailored for policy makers and

managers concerned about practical measures that can be adopted with respect to AMES. The study also explores the factors that influence national rates of development of automated manufacturing equipment industries in terms of the national economic environment and the characteristics of the producers and users of AMES.

The preoccupation with declining United States competitiveness is augmented by an analysis of the possible reasons for this situation. Baranson examines the impact of general economic conditions — high unemployment, declining corporate profits, inflation — which have depressed demand for capital expansion in general, and AMES systems in particular. The limited support offered by the Governmment of the United States to promote user demand for AMES and the scarcity of capital are further reasons cited. Various industrial organisation and management characteristics on both the supplier and the user sides are discussed (lack of strategic planning for manufacturing, weak user-vendor relationships, management-labour antagonisms and weak backward linkages to component suppliers). Finally, the lack of aggressiveness in international marketing by United States firms, in contrast to Japanese firms, is discussed as contributing to declining United States competitiveness. This argument is interesting in itself, since it reflects the broader differences between United States and Japanese styles of doing business. In particular, the strong linkage between the Government of Japan and corporations in that country and the support given by the former to the latter may also reflect different contemporary patterns of transnationalization and the relationship between TNCs and the nation-States that spawned them. There seems to be a much greater "nationalistic" character to Japanese TNCs than to those from the United States.

An informative section of the book contains company profiles for selected United States, Japanese and Western European AMES producers, with each profile describing the background, current position and corporate strategy of the firm. This section would have been strengthened by an analysis of how those corporate strategies differ from prior approaches and what this might mean for the international flow of AMES and the specific role that the associated firms, mainly TNCs, would play. However, this is a complex analysis in itself and may have been beyond the intended scope of the book.

These two books have been written from what may be called an explicit industry viewpoint. In that sense, they are frank and forthright analyses of the technology and its implications and of considerable value to policy makers, managers and researchers. They make no attempt to explore the implications of these technologies for developing countries nor to take any real theoretical position.

IMPACT ON DEVELOPING COUNTRIES

The book by Kaplinsky and the collection of papers edited by Jacobsson and Sigurdson are somewhat different in their orientation, both being explicitly concerned with the impact of microelectonics-related technologies on developing countries. Kaplinsky's report, based on a study for the United Nations Industrial Development Organisation (UNIDO) is characterised by a liberal, neo-classical position flavoured with the right amount of radical rhetoric but ultimately emerging as a technologically determinist standpoint. Unfortunately, it typifies a school of research on technology and development that has emerged in recent years which resorts to a variety of grand theoretical schemes and extensive empirical research, all ostensibly aimed at developing more informed policy options for developing countries; one wonders, though, whether the effect of these efforts is not simply to mystify new technologies and provide an ideological justification for their diffusion into the third world, a legitimising function which would be extremely useful, among others, to TNCs involved in these technologies.

Kaplinsky's study begins with an overview of research and theorising on long waves (*à la* Kondratieff) and the perspectives they offer on computer-aided design (CAD). Research on long waves is obviously important, but the field is fraught with empirical inadequacies, a multiplicity of theoretical interpretations and considerable ambiguity about their relevance to large portions of third world economies. Also, much of the interest in long waves derives from concern over the current "crisis" in the developed world. In this reviewer's opinion, crisis is nothing new for the developing countries — in fact, that is what underdevelopment is all about.

While the crisis in the developed world certainly influences their economic and political strategies *vis-a-vis* the developing countries — and in this sense affects the latter's development patterns — it seems far more sensible to take the fact of underdevelopment as the starting point for the analysis of options to deal with this crisis and to deal with the newly emerging technologies from that standpoint.

Furthermore, the long waves analytical approach, though aimed at "situating [the] contemporary crisis in a broader sweep of history" (p. 19), deflects attention from a very simple and practical point, i.e., that throughout history, there have been periods of rapid technological advance, and that with each such wave, there has been enthusiasm about how these technologies are going to solve civilisation's pressing problems. But when the dust has settled, things basically look pretty much the same — a few improvements in some sectors and for some strata of society, but the majority of the disadvantaged population is either in the same position as before, or worse off. The discovery of

long waves does little to help in dealing with this process, except to create a tendency to lean more heavily on technical solutions to what inherently is a structural and political problem.

The bulk of Kaplinsky's book is devoted to a description of CAD technology, CAD markets, the CAD industry and the benefits of using CAD. The information is based on extensive interviews with CAD suppliers and users in the United States and the United Kingdom and is fairly interesting — though it is not clear for whom it is useful. An insider in the industry would probably not find it very revealing, and policy makers in developing countries would probably need to know a great deal more, especially with respect to what the adoption or non-adoption of this technology implies for socio-economic development in their own countries.

Following the descriptive section, an analysis is made of the implications of the diffusion of CAD technology for the competitiveness of developing countries. The major conclusion is that CAD is "likely to diffuse first to precisely those non-traditional sectors in which exports grew most rapidly during 1970-1978 and in which many LDCs [less developed countries] are hoping to specialise in the 1980s. Consequently, unless LDCs are able to introduce CAD in these sectors, they are likely to display diminished competitive capabilities in the market place and be forced back to the extent that these are less significantly affected by CAD technology" (p. 109).

However, this conclusion, if true, can be generalised only to a limited extent. Only a small number of developing countries have a sizeable manufacturing sector; others are still dependent largely on exports of primary commodities, and the implications for them of CAD, or any other new technology, are far from clear. Secondly, there seems to be a basic assumption throughout the analysis that enhanced trade with developed countries is essential to the growth of developing countries. Such trade is obviously important, but growth of a national economy also depends substantially on other factors — growth of domestic industrial production, markets, agricultural production and the service sector. The role of international trade needs to be seen in this broader framework of socio-economic development, rather than to be singled out as the central issue of concern.

A brief analysis towards the end of the book deals with the role of TNCs in the CAD industry. Kaplinsky identifies four trends in this regard: the penetration of the CAD market by a number of existing electronics firms producing computers and terminal screens; an increasing tendency for established engineering firms to encapsulate CAD technology in their efforts to supply automated technologies to industry; and a trend towards the transnationalisation of CAD

technology production, i.e., a tendency towards the increasing incorporation of CAD technology within TNCs. The fourth, and more important trend for Kaplinsky, is that TNCs are becoming particularly heavy users of CAD and that TNCs are becoming the prime targets for CAD suppliers.

Given this growing TNC role in all phases of CAD, Kaplinsky presents two possible and equally tenable future scenarios with respect to TNC locational decisions: (1) A reduction in incentive to locate production in developing countries, because electronics technologies diminish the low-labour-cost comparative advantage of developing countries and because such locations would be too far from final markets and technology suppliers. (2) A tendency to locate design in advanced countries and maintain productive facilities in developing countries; this is being made possible by transborder data flows which overcome the problems and costs associated with distance. This analysis of the changing strategies of TNCs is of some interest as far as location decisions are concerned. However, it might have been more interesting if the analysis had gone further into investigating the possible changes in the structures and strategies of TNCs and perhaps the implications of these changes for the structure of work, the rationalisation of production, the implications for national sovereignty and, most importantly, for the development process in developing countries. Unfortunately, the technocratic bias of the book leaves little room for consideration of these fundamental problems. Thus, the final insight that one is left with is that TNCs will either locate in developing countries, or will not — hardly a revealing or useful bit of information for a policy maker in a developing country.

The readings in this book edited by Jacobsson and Sigurdson are subject to the same criticism. Indeed, the best paper in the book is the concluding article by Andrew Jamison, "Monitoring the monitorers: a critique instead of a conclusion". In a general comment on the collection of papers, which includes one on CAD by Kaplinsky based on his UNIDO study, Jamison observes (p. 229):

> . . . I think it is important to examine quite closely what the experts are up to, partly because the issues they are discussing are intrinsically important to all of us, and partly because the experts, in this book anyway, seem to have gotten so carried away by the "revolutionary" potential of these new technologies that they have largely forgotten the people that these technologies — or any technology, for that matter — are ultimately meant to serve. Because of their technical — and businessman's — orientation, the contributors to this volume have tended to overemphasise the technical side of the microelectronic challenge, while almost completely disregarding the larger social and human implications.

Jamison takes this as his point of departure to initiate a more general critique of the paradigm that underlies the study of technical change and innovation, arguing that this paradigm suffers from a preoccupation with the internal dimension of technology, with little attention being given to the social context within which technology is developed and used. It is essential to pursue this line of argument both in terms of its general significance for research in this area, and in terms of the more specific question of how this technology is associated with a growing process of transnationalisation of production, how the structures and strategies of TNCs are changing in connection with new technologies, and what this means for the rationalisation of production, the control over economic activity, the character of work, and the implications for social and economic development in the third world.

Except for Jamison's paper, none of the other articles dwells on this subject. Nevertheless, Sigurdson's paper is a useful analysis of microelectronics technology. It discusses the growing control over research and development resources (which are increasingly in the hands of TNCs); the increasing and differential interests of key actors in this technology — nations, TNCs, trade unions and consumers; and the emerging trends in economies of scale, market control and technology sharing. The discussion about the role of TNCs dwells on their growing control over research and development resources, the seemingly marginal relevance of developing countries to their marketing and production interests, their reluctance to sell their technology unless they gain access to markets of new technology and the potential contribution they can make to the creation of a technology culture in various countries, including developing ones. While Sigurdson does see prospects of increased TNC involvement in high technology in developing countries, his view is that this is unlikely to occur in the near future, but may happen at a later stage, when the technology has become more mature. He does not see any possibility of developing countries leap-frogging into this field; he argues that the high costs associated with these technologies, the small domestic markets and the increasing tendency for technology sharing among developed countries make such a prospect unlikely.

A paper by John Bessant on the diffusion of microelectronics provides a brief overview of the technology and an analysis of the factors that influence its diffusion. Interestingly, he concludes that the facts reveal that the rate of diffusion of microelectronics has been far slower than generally believed, that there are possibilities for developing countries to enter selectively into this technology (somewhat contrary to Sigurdson), but that a major barrier is the growing industrial concentration of the information-technology field in the hands of TNCs. Hence, he says (p. 63):

> Given that the relationship between the multinational companies and the developing countries is already problematic, with many undesirable aspects, this may pose a major threat. In particular it seems likely that a trend of this kind may severely affect the level of technological dependence experienced. Furthermore, since much of the power and control over resources which the multinational corporation has is dependent on flexibility of responses on a worldwide basis, the advent of sophisticated communications technology may well be to their advantage.

The other papers in the collection deal with various dimensions of electronics. Kurt Hoffman and Howard Rush provide a condensed version of their study of the implications of microelectronics for the garment industry, which falls into the same category as the Kaplinsky study. The paper on CAD by Kaplinsky has been discussed earlier. There are also papers by Staffan Jacobsson and Thomas Ljung on the implications of electronics and automation for the engineering industry; by Jacobsson on numerically-controlled machine tools; by Philip Maxwell on Argentinian experiences with electronic production; and by Jon Sigurdson and Pradeep Bhargava on the electronics industry in China and India. The general comments of Jamison apply in varying degrees to all these papers, though it should be noted that, taken together, they do have a certain information value. Their failing is in their systematic neglect of the social dimension of new technologies.

THE GLOBAL RACE

The book by Ernst, based on his study for UNIDO, differs dramatically from the previous studies and is indeed one of the most excellent examinations of the subject that this reviewer has read. It combines theoretical sophistication and sensitivity with a strong pragmatic orientation and empirical base and should be exciting to scholars in this field as well as informative and pertinent to policy makers in developing countries.

The stated purpose of the study is "to set out a framework for analysing the interaction between the introduction of new technologies and the restructuring of world industry, particularly with regard to emerging new international locational patterns" (p. 1). From the start, the study is situated in a broad overall conceptual framework that draws intelligently from available literature and data. An underlying concern throughout the study has to do with the implications of recent breakthroughs in the design and manufacture of microelectronic circuits for developing countries trying to implement strategies of transition to more self-reliant patterns of industrialisation. The study painstakingly covers most of the major issues that relate to this subject. It begins with an analysis of

innovation and industrial restructuring seen in an historical perspective and then goes on to explore the crisis in the semiconductor industry, where Ernst argues that, contrary to popular belief, the electronics industry is highly vulnerable to cyclical changes in economic factors and that this explains the particular strategies adopted by the key actors in this industry. Chapter three explores the economics of semiconductor manufacturing in an attempt to identify the impact of innovation on market structures and on patterns of control over strategic assets on this industry. The next section explores current and future trends in the software sector. The fifth one addresses the interaction between technological advances and industrial restructuring, and the final chapter discusses the implications of breakthroughs in this technology for global patterns of technological dominance and dependence.

Unlike most other writers on this subject, Ernst does not exhibit a fascination with the technology itself and indeed sets out to find out what it is, besides innovation, that can explain the way the industry is moving, and what this means for the international division of labour, and for development in the third world. He explicitly concludes that "innovation has been an important but by no means exclusive factor behind the new patterns of industrial restructuring and international location which have been recently emerging in the semiconductor industry. . ." and that ". . .the use of new microelectronics technologies and the distribution of control over the relevant innovative capacities conditions, but does not determine by itself the restructuring of world industry. In the final analysis, industrial restructuring is determined by the economic, social and political power structures within which the social actors who are engaged in industrial production, trade, and in the exchange of production factors, have to operate" (pp. 3-4). These are bold statements to make, but extremely refreshing to their frankness, and powerful because they are backed up by a strong empirical base.

Based on his findings, Ernst argues for the need for an alternative conceptual approach to the problem of innovation and industrial restructuring. This is in line with Jamison's plea for a new paradigm for innovation research, and both calls need to be addressed urgently if a more realistic and comprehensive understanding is to be gained about the implications of new technologies for development in the third world.

Though Ernst is only partially successful in developing such a new conceptual approach, he raises some crucial questions. In particular, he points out that while new technologies themselves influence the nature of production, other factors are equally, if not more, important — the stage of development of the relevant industrial sector, the interrelationships between this sector and others, the

patterns of conflict and co-operation between major actors in this sector, and political and geopolitical factors (p. 283):

> It is the complex and dynamic interplay of these various factors which sets the stage for decisions on whether or not to apply a new technology and how rapidly. It also conditions the kind of complementary restructuring of organisational patterns, strategies of major actors and prevailing modes of international trade and investment allocation.

This point has powerful implications for a number of questions, including those that relate to the role and structure of TNCs in this industry. It raises questions about the extent to which economic rationality is the sole principle for TNC location decisions, whether market forces are adequate to explain technological adoption, and whether the nature of TNC expansion into the third world can be predicted solely on the basis of a technologically determinist analysis. Indeed, Ernst argues for the need for a critique of three key elements of conventional wisdom on international economic relations: technological determinism, the new international division of labour (which, he argues, has fallen into the trap of "mono-causalism" by over-emphasising the search for low cost labour as the dominant factor in international restructuring and location decisions), and "those theories of the internationalisation of capital which tend to restrict their analysis to a specific branch" (p. 286). Intersectoral linkages are crucially important in understanding the process in any one specific industrial sector or branch.

On the basis of this critical perspective, Ernst proposes that an alternative conceptual approach should be based upon two factors: the modes of capital accumulation prevailing in a specific historical and geographical context, and the related changes in the social relations of production, particularly with respect to work. These concerns are then further specified in terms of the rationalisation of variable capital (that is, of the use of labour), which leads to the need for an analysis of organisational and managerial innovations to improve the efficiency of use of physical inputs and capital in the production process, in terms of new forms of plant layout, production scheduling, new more flexible production patterns, methods to increase levels of machine use, as well as new forms of labour management (quality circles, etc.); and the increasingly rationalised use of intangible production inputs — knowledge and information inputs, ranging from basic design to systems and applications software.

It is to be hoped that the initial outline for a new conceptual approach to the study of innovation will be carried further by Ernst (and by Jamison) and others in this field. Until that time,

unfortunately, the present dominance of technological determinism will presumably continue and, in so doing, distort our understanding of the social dimension of innovation and of the changing character and role of TNCs with respect to technology and development in the third world.