TECHNOLOGICAL DIFFUSION
THE THEORY AND SOME METHODOLOGICAL SUGGESTIONS
FOR THE STUDY OF THE BRAZILIAN CASE*

Giovanni Dosi

November, 1984

Project Social Impact of
Development - BRA/82/024
Final Version
November, 1984

TECHNOLOGICAL DIFFUSION
THE THEORY AND SOME METHODOLOGICAL SUGGESTIONS FOR THE STUDY OF THE BRAZILIAN CASE*

by

Giovanni Dosi**

---

* Consultancy Report for IPEA/CNRH, Brasília. The Consultancy has been supported by the International Labour Office (ILO).

Venice and SPRU, University of Sussex,

Project Social Impact of
Development - BRA/82/024
Final Version
November, 1984

TECHNOLOGICAL DIFFUSION
THE THEORY AND SOME METHODOLOGICAL SUGGESTIONS FOR THE STUDY OF THE BRAZILIAN CASE*

by

Giovanni Dosi**

Consultancy Report contracted by Project BRA/82/024 (ILO/UNDP and CNRH/IPEA), Brasilia.

* Consultancy ~~Report for IPEA/CNRH, Brasilia.~~ The Consultancy ~~has been supported~~ by the ~~International Labour Office~~ (ILO).

** [redacted] Venice and SPRU, University of Sussex,), UK

Catálogo: **IPEA - Catálogo da Biblioteca (Brasília/Rio)** (Pop: 48949)
Índice : **Número de Chamada**
Busca : **621.381 d723**

Documentos Encontrados

CATÁLOGOS | ÍNDICES | PESQUISA | APRESENTAÇÃO

AUTORIA:	Dosi, Giovanni
TÍTULO:	**Technological diffusion:** the theory and some methodological suggestions for the study of the Brazilian case
IMPRENTA:	**Brasília :** IPEA, 1984.
DESCRIÇÃO FÍSICA:	53 p.
Resumo:	Apresenta um conjunto de observações teóricas e metodológicas destinados a subsidiar o projeto de pesquisa do IPEA sobre a difusão de novas tecnologias microeletrônicas na indústria braileira.
NOTAS:	Incl. ref. IPEA. CNRH; OIT, Genebra. Project Social Impact of Development. BRA/82/024 Fotocópia.
ASSUNTOS:	Difusão de Inovações Microeletrônica Nova Tecnologia Brasil
NÚMERO DE CHAMADA:	**621.381 D723**

LINKS .

Brasília

Documento(s) 1 de um total de 1 encontrados.

Generated by POTIRON OrtoDocs® 2000 [1060076 threads at 0 ms. Build 192]

CONTENTS

Some notes on technological diffusion

(i) Introduction

What follows is a set of theoretical and methodological observations, meant as a framework for the IPEA research project on the diffusion of new microeletronics technologies in the Brazilian industry.

It must be noticed that the "state-of the art" of economic theory is far from having achieved a thorough and satisfactory conceptualization of the mechanisms, determinants, and effects of the diffusion of new products and processes. In addition to the inherent difficulty of the issue, it may well be that this is also the outcome of an inadequate "tool box" of the prevailing theoretical paradigm in economics, based as it is on the hypotheses that a) technology is a freely available good, b) all the agents are equal in their technological capabilities, c) institutional and social conditions are, generally speaking, irrelevant to technological development, d) all behaviours can be reduced to a unique maximizing procedure. What follows, on the contrary, is an exploration of some of the issues related to technological diffusion, whenever one makes a radical departure from all these assumptions.

The existing literature on diffusion may probably be distingnished into two broad sets [1]. A first one pioneered by Mansfield and Griliches sees the diffusion process essentially as a mechanism~~s~~ of diffusion of *information*, akin to the spread of, say, a desease in a population of potentially infectable members. In a sense, that tradition - which was developed and refined among others, by Davies (1979) - assumes that technology is *potentially* a free good, while at the same time introducing *imperfect information* of the would-be adopters and/or different incentives and constraints facing the adopters themselves according to their structural characteristics (size, etc.) or the characteristics of the innovation (cost, minimum scale, expected differential profitability, etc.).

---

1) For a review of the literature see Stoneman (1984).

The process of diffusion is therefore approximated either by a logistic curve, whereby the degree of "infection" is a function of the amount of population already "infected", or by the family of curves which can be generated by a PROBIT model of stochastic adaption (cf. Davies (1979)).

A second stream of investigation, lead by David (1975), mantains a somewhat stricter "rationality assumption" of the agents, while stressing structural differences in the incentives and/or the economic contexts facing each individual agent, so that, for example, in David's analysis, it is "rational" to adopt mechanized agricultural equipment, at first, only for big farmers, with high labour costs, etc. Only later with the improvement of the machinery, its falling relative cost, etc., the adoption becomes "rational" for the smaller farmer, etc.

Somewhat overlapping with these two streams of investigation, some analysis has been undertaken on the international diffusion of innovation (see, in particular, Nabseth and Ray (1974)), trying to assess the determinants of different observed patterns of technological diffusion, within and between countries, in relation, amongst other variables, with the investment costs, the location of the original innovation, firm sizes, etc.. It is remarkable that, until recent contributions (and with the exception of David (1975)) the fundamental inter-relation between <u>supply</u> and <u>demand</u> conditions in the diffusion process has been largely neglected in formalized models[1]. One of the first models accounting for supply/demand inter-action is Metcalfe (1983), who analyses, among other things, the effect of further improvements in the innovation upon the size of the population of potential adopters and the impact of a changing supply-price upon the incentive to diffusion in demand. Along somewhat similar lines, t~~o~~he models by David and Olsen (1984) and Ireland and Stoneman (1983) introduc~~d~~e

---

1) In this respect, the more historical investigations of Freeman (1974) Rosenberg (1976) and (1982), Landes (1969) are certainly much deeper and richer.

also the role of technological expectations, thus formalizing a seminal hypothesis by Rosenberg (1976) and (1982). Fruitful as they are in understanding under highly "stylized conditions" the impact of expectations about future developments upon present technological decisions, these models mantain, however, the limiting assumptions that (i) the technological future can be forecasted with some rational procedure and (ii) technological decisions can be adequately expressed through maximizing behaviours.

Outside the strict realm of formal diffusion theory, the patterns of international technological diffusion, as known, have been discussed - in some looser manners - by product-cycle theorie of international trade, under the general hypothesis that the main determining factor is related to the conditions of demand in each national market. Conversely the literature on development, has often stressed the role of asymmetric institutional economic and power conditions as one of the fundamental obstacles to technological diffusion to developing countries of best-practise processes and products.

Finally, regional economics and economic geography have approached the issue of spatial diffusion of new technologies[1] in ways which often mirror the analytical framework of diffusion theory developed in industrial economics, mentioned above.

The discussion which follows, drawing from the foregoing streams research, tries to suggest some hypotheses on the determinants of intra-sectoral and inter-national patterns of diffusion, whenever one introduces some rather general assumptions on the nature of technology, the behaviour of the economic agents and the social/institutional context.

In order to highlight some of the theoretical issues of diffusion in a rather general way, the reader is invited to think of the relatively slow patterns of diffusion of innovations which one can emprically observe (both within and - even more so - between countries). Were diffusion only a problem of information, one could hardly explain it, especially in an age of rapid

---

[1] See, among others, Hagerstrand (1967), Hansen (1972), Brown (1981), Camagni, Cappelin and Garofoli (1984).

circulation of every non-proprietor piece of knowledge, news, etc.

Moreover, it is easy to see the points of weakness of the prevailing conceptualization of diffusion patterns- analytically similar to the diffusion of, say infections. Take the example of the transmission by contact of, say, a venereal desease: the carriers can be assumed to be - to different degrees - cautions not to spread it or neutral, while certainly the potentially infectable population tries - if possible - not to catch it. Conversely, in the case of innovations, and in particular those that are equipment embodied, their producers positively try to "diffuse the desease", while the "infectable population" is, at least potentially, willing to catch it. If anything, it is puzzling to imagine that the two processes of diffusion (deseases and innovations), characterized by deeply different behavioural mechanisms may generally lead to a similar aggregate pattern. In the medical metaphor, this paper suggests some tentative hypotheses on the factors determining both the willingness, the capabilities to catch the "new technological deseases", jointly with the retardation factors, which - we shall argue - have to do more with the nature of technology and the way it is incorporated into the economic system rather than a simple problem of information.

Since the present paper is meant also as an introduction to an empirical research on the patterns of diffusion of new technologies in the Brazilian industry, each of the following sections will be accompanied by some empirical questions, which may help the investigation.

(ii) Some hypotheses on the process of Technological diffusion. The diffusion in supply

By way of an introduction, it may be useful to distinguish between diffusion in supply and diffusion in demand. Clearly the two - in our view-are deeply inter-linked. However, the mechanisms of diffusion possess partly different natures which deserve separate investigations. Let us start from some fundamental features of technology and technological advances. First, technology, far from being a free good, possessed varying degrees of appropriability, tacitness, comulativeness.[1]

- Some important implications of this view are that:
  - The patterns of both innovation and imitation by individual agents and their degree of innovative success depend in a crucial way, also, on the technological capabilities of the agents themselves, their field of expertise, the "heuristics" and the "tacit" knowledge each firm embodies;
  - As a consequence, the economic agents, far from being equal, show varying degrees of technological asymmetries which contribute to determine individual and collective economic performance within each industry.

Second, in such a world, the rate of diffusion of innovation, within any one national industry, or, as we shall see, on international level, is an inverse function of these degrees of appropriability, tacitness and cumulativeness of technology itself, and, clearly, a direct function of imitability and transferability of the innovations.

Moreover, the general case appears to be that technological learning is, in a sense, a joint production with the proper manufacturing process. In other words, technological upgrading is often contextual to the actual production of commodities, the problem - solving activity is embodies, etc. Not very much can be simply learned from blueprints.

In order to illustrate these points let us imagine an industry producing a set of products which can be ~~i~~univocally ranked by their performance characteristics. In figure 1, one assumes that this performance features of the product, weighted with the costs of production, can be represented by the index θ.

---

[1] For a fascinating empirical investigation of these issues, see the research, presently underway, coordinated by R. Levin and S. Winter at Yale University. For an investigation of similar topics on the italian industry, see Onida (1984). For theoretical treatments, cf. Nelson and Winter (1982) and Dosi (1984).

Thus, technical progress here is assumed to be entirely reppresented by the increase in that θ - index. Conversely, the x-axis represent a proper indexing of the firms in the industry, weighted by their share in production. Suppose that at time t = 0 the broken line AA' rappresents the distribution of firms according to their technological performance (measured by θ). Thus the *degree of asymmetry*, which is clearly an *inverse* measure of the diffusion in production of best-practice products, is related to the *slope* of the AA' line. Note that to make things simple, we assume that the θ-index is cost-weighted and the products of different "technological vintages" are homogeneous, in a way that the structure of demand becomes irrelevant: simply the "backward" producers in order to sell will have to charge prices corresponding to lower profits. This extreme hypotheses are clearly unrealistic and we will relax them later on. For the time being, however, they will help our argument. In our stylized rappresentation, firms continue to innovate and/or imitate the "best-practise" products. The lines BB' and CC' rappresent two possible developments over time.

Notably, BB' shows a trend toward *increasing asymmetry* while, the CC'line highlights a *convergence tendency*. We must now wonder: what affects these possible alternative trends? Part of the answer stems from our foregoing remarks:

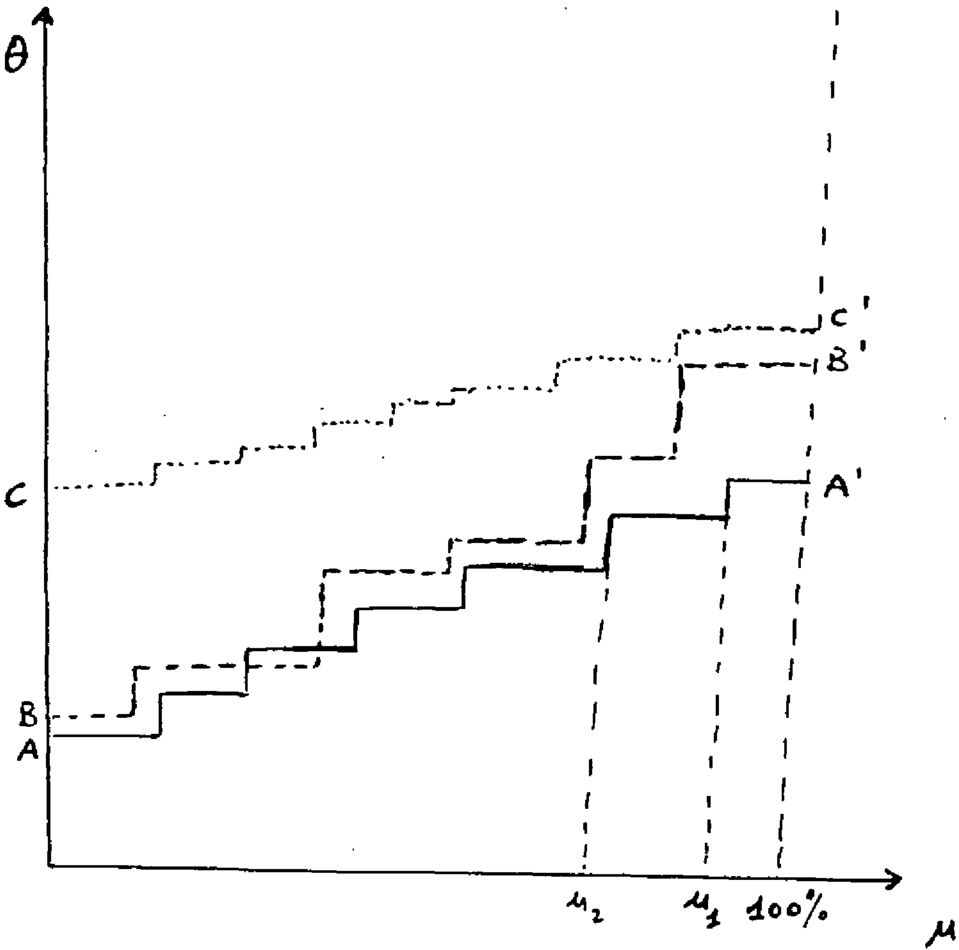
(i) The higher the cumulativeness of technical progress the higher is the probability of the best-practice firms to mantain/increase their lead. Similar considerations apply to the degrees of appropriability of innovations, etc.

(ii) Conversely, the easier it is to "watch and learn", do reverse engineering, etc., the higher, other things being equal, is the degree the diffusion (cf. for example, the CC' line).

(iii) It is important to notice that the issue of cumulativeness relates to that of *capabilities*: to repeat, the *present* technological position of each agent is one of the determining factors of its *future* technological performance.

ig. 1. technological asymmetries, innovation, diffusion in production

Δ /



weighted

θ = index of cost-weighted performance of output
μ = firms indexed in relation to output shares

FIGURE 1: TECHNOLOGICAL ASYMMETRIES, INNOVATION, AND DIFFUSION IN PRODUCTION

M

μ

Moreover:

(iv) One can easily notice that the diffusion of any one vintage of innovation may well never reach 100%, being superceded by "better vintages".

(v) More generally, one of the determinants of the degree of asymmetry (which, to recall, is an inverse measure of the degree of diffusion) is the rate of technical progress. The higher the technological opportunity, other things being equal, the higher the degree of asymmetry.

(iv) Apart from strict technological cumulativeness, other factors which are asymmetry-inducing (and, thus, diffusion-obstacles) are economies of scale in production/research/marketing, etc.; various forms of "externalities" (for example, special user-producer relationship enjoyed by virtue of location, etc.); ~~A~~availability/absence of particular skills, services, etc.

(vii) It can be seen that the degree of asymmetry is directly linked with entry-and mobility - barriers within each industry, quite apart from (and in addition to) the possibility of collusive behaviours of the technological and/or market leaders. In other words, inter-firm differences in lato sensu ~~T~~technological capabilities (among the existing producers and between producers and potential entrants) perform as structural barriers to intra- and inter-industrial mobility. An implication, as we show at greater length in another work[1], is that, other things being equal, the levels of profit margins (for the leaders and for the industry) and the variance in the margins themselves are a positive function of the degree of asymmetry of the industry;

---

1) Dosi (1984)

(viii) It is important to notice that, from a behavioural point of view, the existence of technological asymmetries plays at the same time as an entry barrier and as an incentive to innovate - in virtue of the differential profits and market-shares that technological upgrading generally yields. Which one of the two effects will prevail again depends on the *nature* of the *technology* (cumulativeness, appropriability, opportunity, etc.) *compared with the technological capabilities* of "backward" producers and potential entrants.

If these considerations are correct, then both the patterns of diffusion in production and the long-term rates of technological change are a function of the interaction between the intrinsic features of each technological paradigm[1] and the endogenously-generated set of stimuli/constraints which the moving thread of leads/lags poses to each firm.

These remarks already suggest a set of important questions for the empirical investigation. For example:

- What is the broad nature of the technologies to be investigated? (i.e. what is the nature of the "technological paradigm"? What are the most important technical and economic dimensions of the "trajectories" of progress?)
- What are their degrees of appropriability/cumulativeness/ "tacitness", etc.?
- What is the "world" rate of technical change?
- Are there static and dynamic economies of scale?
- What are the technological capabilities of domestic producers?
- How big is the lag vis-à-vis "frontier" producers?

---

1) For a discussion of this concept, see *Ibid*.

(iii) *The process of technological diffusion. Diffusion in demand*

It is now time to relax some of the simplifying assumptions introduced above and explicitly discuss the interaction between supply and demand factors. Suppose that the foregoing discussion relates to an intermediate component or a capital good, which is then bought and adopted by a user-industry.

As implications of the discussion above, let us suggest the following propositions:

(a) all technical progress (and especially product-innovations) in the innovation-producing sector expand the population of *potential adopters* of the innovation.

(b) the rate of technical progress, *ceteris paribus*, positively influences the *actual* rate of diffusion in demand, both via improving performance in the goods and falling performance-weighted relative prices vis-à-vis the final output;

(c) In the other causal direction, the *size and rate of change* of demand is likely to exert a positive influence on the rate of technical change in the supplying sector (we would call it the "Schmookler effect"[1]).

(d) An effect of a similar nature upon the technological levels of the supplying industry is generally induced by the technological *levels and requirements* of the demanding industry (its degree of sophistication, the complexity of its products, etc.)

(e) Quite often the existence of technological bottlenecks, unsolved technical and organizazional "puzzles" in the using-industry represent - as Rosenberg puts it[2] a powerful "focusing mechanism" which influence the technological trajectory[3] of progress in the

---

[1] cf. Schmookler (1966)

[2] Rosenberg (1976)

[3] For a discussion of this concept, see Nelson and Winter (1977), Dosi (1982), Sahal (1981).

innovation-producing industry[1].

(f) In the opposite direction, the nature of the patterns of technological progress in the innovation-producing sector generally exert a powerful influence on the trends in technical progress for the users and even on the nature of their products.

All these considerations taken together allow us a first overview of the mechanisms affecting technological diffusion in the user-sector.

First of all, one property has to be clear: the process of diffusion of an innovation (say, a new machine tool) in the user-sector is, in a essential sense, a process of innovation and technological change for the user itself. In other words, far from being simply a decision of buy-and-use, it generally involves a process of learning, modification of the existing organization of production and, often, even a modification of products. Thus, a crucial consequences is that, also the process of adoption of innovations is affected by the technological capabilities, production strategies, forms of productive organization of the users. One can see here a first reason why empirical evidence shows relatively slow diffusion patterns over time: quite apart from any kind of "non-optimizing behaviour" or "information failure" - as often suggested by the prevailing literature -, the "pecking-order" in the adoption process i~~n~~s influenced by the technological asymmetries in the user sector. Other things being equal, we would therefore expect a rate of diffusion of any one innovation or cluster of new technologies which is higher the higher the pre-existing technological levels of the users.[2]

More generally, one may distinguish between three broad set of factors which affect the patterns of diffusion of new technologies (say, new kinds of production machinery) in any

---

1) Please note that, here, for sake of simplicity, we are making a rather extreme distinction between users and producers of innovation. For a more complete discussion, see below.

2) For an argument conceptually similar on the diffusion of microelectronics in "downstream" sectors, cf. Pavitt (1984a)

one user sector, namely, (1) strictly technological factors; (ii) factors related to the nature of economic signals and (iii) factors related to corporate organization, work processes, patterns of industrial conflict, institutional contexts.

Let us examine them in turn.

Technological factors.

We have already discussed them at some leghth. To recall:

(i) All technical progress in,say, "machine-building", is likely to induce an expansion of the population of potential adopters. In figure 2, the asymptotic line A moves upward as a function of time and of θ (the same "technical progress index" as in figure 1, expressing the "performance" of the machinery). A first implication is that the empirical pattern of diffusion, say the line OP (figure 2)- as suggested also by Metcalfe (1983) - is the joint outcome of a movement along diffusion curves and a movement of the curves themselves (say from ll' to dd', gg', etc.)

(ii) In addition, a technology-related factor, affecting the slope of each of the notional curves ll', dd', etc. (and thus also the slope of the actual OP curve of diffusion) is represented - as mentioned - by the technological capabilities of the population of the adopters. Even if we assume that the new technology would be ideally profitable for all of them, the patterns of asymmetry in their technological capabilities influences their pace of adoption. In other words, it may well be that the adoption of any one innovation is notionally economical for a certain population of potential adopters and that all of them know about its existence and its main features. However, most of these potential adopters may as well not utilize it for the simple reason that they do not have the technological organizational (and, sometimes, financial) capabilites of doing ~~it~~ so. To put it roughly, they do not adopt because they do not know how to. In turn the patterns of diffusion shape the performance of each firm in the user-sector. Figure 3 illustrates such a case. Imagine that the new technologies of production are superior to the old ones irrespectively of relative prices [1] and that the adoption of these technologies is univocally reflected in the cost of production. (please not that this is only a simplifying device, for clarity of exposition: any complemetary effect on the quality, reliability, etc. of the final products would only re-enforce our argument). Under these circumstances the patterns of adoption of the new technologies determines the patterns of asymmetry in the user-industries (as expressed, here, by production cost differentials). Through time, the rate of best-practice technical change (as expressed by the movement down from A' to B', C', etc. in figure 3) jointly with patterns of diffusion of new technologies (expressed by the inclination of lines AA', BB', CC' etc.) determines the moving thread of asymmetries in performance of user-firms.

The reader will have notices the similarity between this discussion and the foregoing one on the asymmetries in the innovation-producing sector. Again, this highlights the fact that processes of innovation/learning/adoption are inter-linked activities amongst both "users" and "producers" of innovations, which determine the patterns of advantages/disadvantages between firms (and countries).

It is remarkable that inter-firm (and, by extension, inter-national) asymmetries play a double role. First, to repeat, asymmetries in capabilities contribute to explain a differentiated pattern of diffusion (as shown in figure 2). Correspondingly, asymmetries in the degrees of diffusion determine differentiated performance (as shown by the slope of the AA', BB', CC' lines, in figure 3). Extending this latter analysis to would-be

---

1) For a discussion, see below.

entrants too, it is easy to see how the pattern of asymmetry in adoption of new technologies provides the structural foundation for both *entry* and *mobility-barriers*, and, so, also the structural ground for the differential profitability of the "leaders" (compare, for example in figures 3 the gross profit margin of the "leader", at t = 0, equal to the segment E_oA', with that of the infra-marginal firm, equal to the segment P_oC_o). A remarkable corollary is that, once given any pricing rule, the "profitability gap" between leaders and followers will be higher, the higher the asymmetry in diffusion (i.e. the higher the slope of the lines A" AA', B" BB', etc.) Conversely, the "competitive conditions" could be approached whenever technical progress would tend to stop and diffusion reach its asymptotic limit[1]. Another interesting corollary is that there are two fundamental mechanisms of technological diffusion. The first, which has been discussed so far, is the increase in the *number* of the actual adopters within the population of potential ones. A second mechanism, equally important, is the increase in *relative size* (and, thus, market shares) of the quicker adopters, due to the competitive edge gained through the innovative process. It is straight forward that the relative balance between the two processes on national and international level will shape the trends in industrial *concentration*.

Economic factors

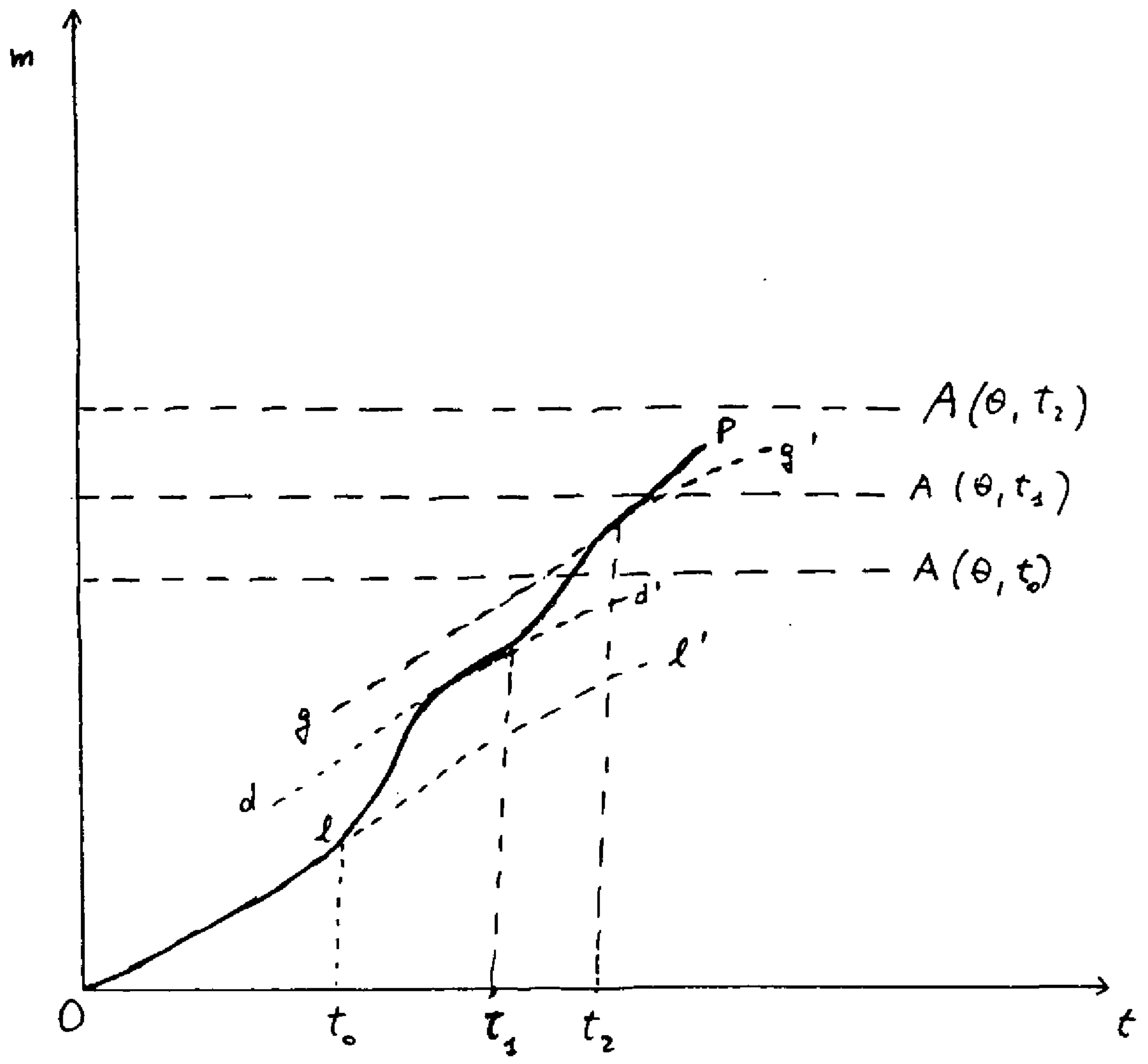
Clearly, the variables related to technological capabilities, etc. are only a part of the explanation of the patterns of diffusion, although a very important one. Obviously, economic factors, related to the set of incentives, constraints, etc. posed by the nature of the markets, relative prices etc. play a crucial role too. Let us start from the impact of relative prices. In another work[2], we argue that the *general case* of modern technological development is characterized by the *unequivocal superiority* of new techniques vis-à-vis old ones. One can see

---

1) We discuss these issues at length in Dosi (1984)

2) Dosi, Pavitt and Soete (1985)

Figure 2. Patterns of diffusion of new technologies in user sectors



t = Time

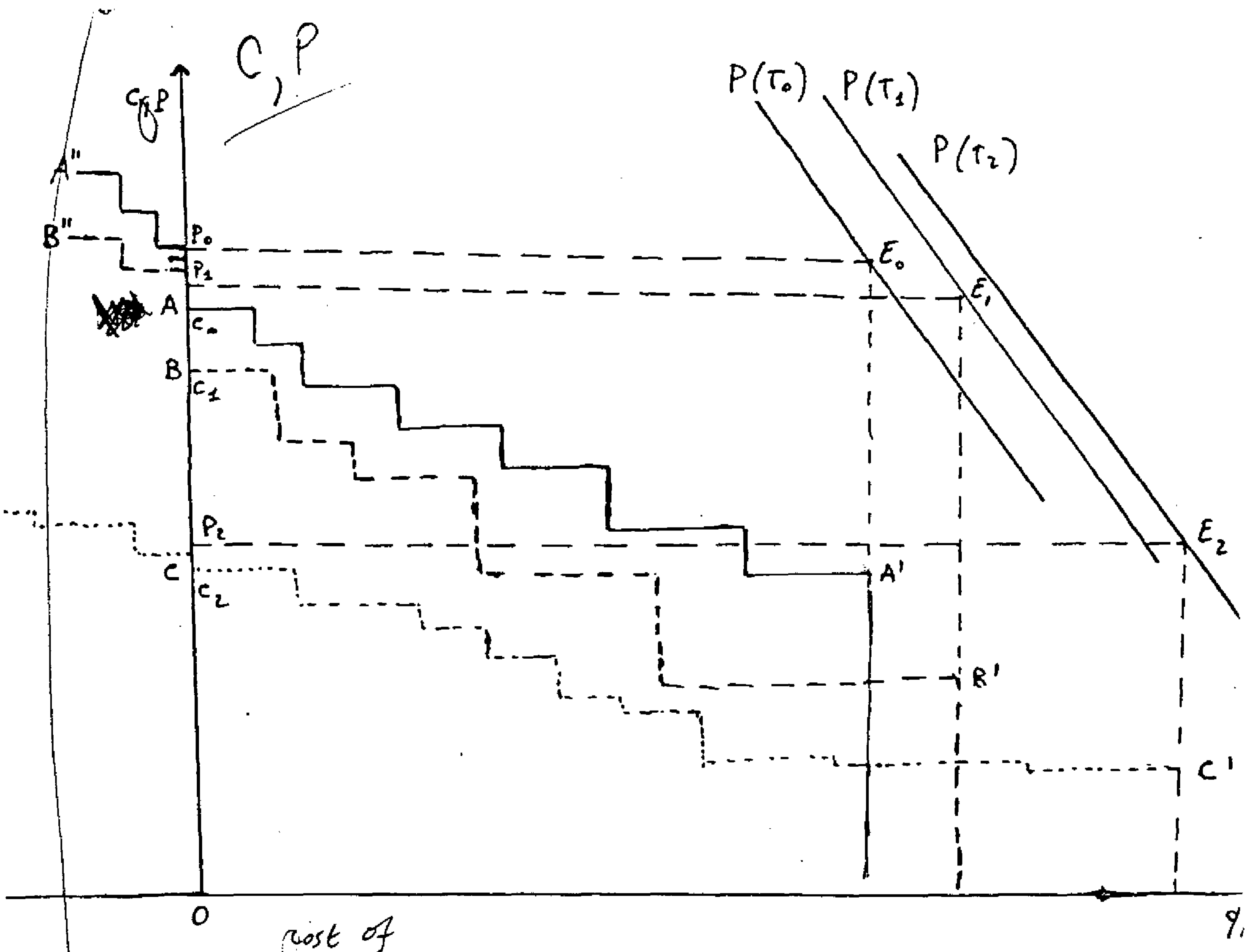
m = number of adopters adopters

A = number of potential adopters

θ = ~~[illegible]~~ index of technological performance of the innovations (see Figure 1 Figure 1)

FIGURE 2: PATTERNS OF DIFFUSION OF NEW TECHNOLOGIES IN USER SECTORS

Figure 3. Diffusion in user sectors and Technological asymmetries



c = cost of production
p = price
q = quantity
μ (μ = 1 ...., n) = firms

FIGURE 3: DIFFUSION IN USER SECTORS AND TECHNOLOGICAL ASYMMETRIES

M

μ

here the radical difference between this view and the prevailing (neo-classical) one,which focuses on processes of static inter-factoral substitution. This is not to say that technical process does not substitutes, for example, labour with capital. It obviously does. The fundamental point, however, is that at the same time it increases also the physical productivity of capital in terms of output so that the general pattern of technological change does not depart too much from Harrod-neutrality.[1] Elsewhere we discuss some technological and behavioural reasons why this is likely to be so.[2] Figure 4 illustrate one of such cases of univocal superiority of the new technique, defined by the wage-profit frontier W_2R_o, as compared with the "old" one, defined by W_1R_o. Clearly, in such cases, the retardation factors in the transition from technique 1 to 2 will have a crucial link with those variables related to capability, learning, knowledge, discussed above. In other words, even if the new technique is economically superior it may well be that firms (countries) do not know how to master it, exploit it efficiently, do not have the necessary skills to run it and/or provide mantainance, etc. In our view, this is a rough but still adequate representation of the general technology gaps in production-processes among OECD countries and, even more so, among industrializing countries[3]. Obviously, one cannot a priori rule out cases such as those depicted by technique W_3R_3 (figure 4), whereby the new technique is "superior" only for high wages but not for low wages[4]. Let us suggest here the hypotheis that, if this occurs,

---

1) That is constancy in the capital/output ratio, at current prices

2) See Dosi, Pavitt and Soete (1985)

3) For the empirical evidence, see Ibid.

4) A necessary warning regarding this case so familiar to neoclassical (but also to some marxian theorizations) is that no general statement can be rigorously made on the relationship between income distribution and choice of techniques, due to the phenomenon of "re-switching", highlighted by the famous "Cambridge controversy" on capital theory. It may well be, for example, that W_3R_3 intersects W_1R_o twice, so that the new technique is profitable for very high and very low wages. cf. Pasinetti (1974).

it is likely to be so at the beginning of the adoption of a new technological paradigm (say at the initial transition from electromechanical to electronic capital equipment), while over time the path of transition between different "vintages" of technologies is likely to approach the transition from W_1R_o to W_2R_o, characterized by univocal superiority and, more or less, Harrod-neutrality[1]. Conversely, it is interesting to notice that in a study on microelectronics - related industries in the UK, Soete and Dosi (1983) found that, if anything, the process of technical progress is akin the transition from W_1R_o to W_4R_4: in other words, in addition to being labour-saving the new technology is also strongly capital-saving. The implications of these alternative patterns of technical change in terms of patterns of growth are far-reaching. For example, if the nature of technological trajectories is similar to the transition from W_1R_o to W_2R_o (and, even more so to W_4R_4), then, it can be shown, any lag in the adoption of the "new" technologies necessarely yields - in an international comparison - an increasing income-gap and wage-gap, irrespectively of the relative price of labour to machines(2).

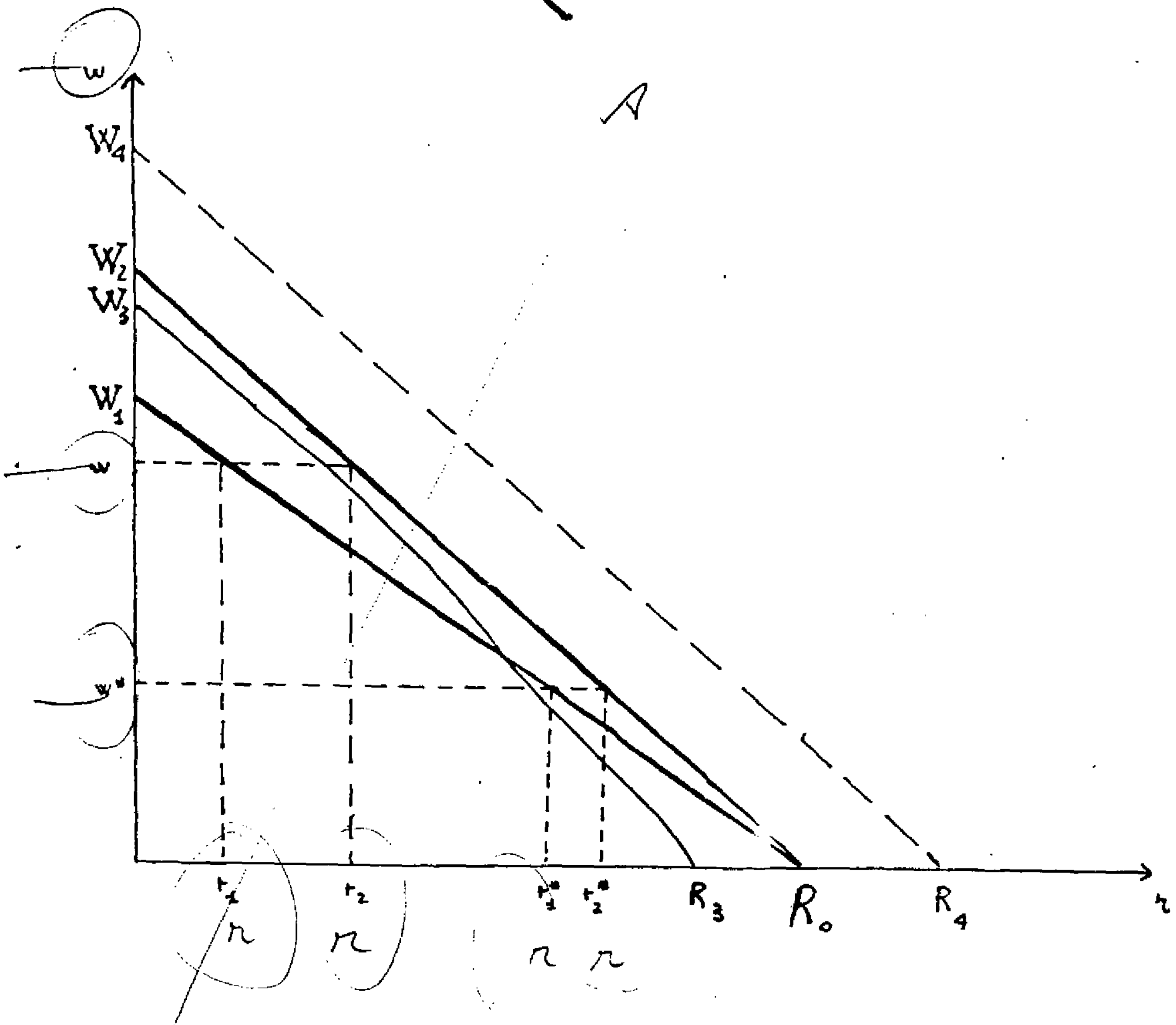
Which one is the case in any particular industry/country/ time is clearly an empirical matter (and an extremely important one to be investigated). A priori, however, one consideration may already be suggested. Even if technical progress is of the Harrod-neutral type (i.e. from W_1R_o to W_2R_o, etc.), it may well be that the behavioural incentive to diffusion of "better" techniques will be nonetheless higher in high-wage firms/countries. Suppose that the wage of the "advanced" country is w and that of the "backward" one is w^*. Clearly the "gain" in terms of profit rate in the former, due to the new technique, $(r_2 - r_1)$ is higher (both in absolute and percentage terms) than that in the laggard country $(r_2^* - r_1^*)$. If one put these consideration together with possible additional "learning costs", negative externalities, etc., which the "backward" country is likely to face, one can see

---

1) Note, incidentally, that this condition would suggest from a normative point of view some argument similar in spirit to the "infant industry" one.

(2) cf. Dosi, Pavitt and Soete (1985).

Figure 4 - Technical progress, relative prices and choice of Techniques



w = wage
r/t = rate of profit

Rate

FIGURE 4: TECHNICAL PROGRESS, RELATIVE PRICES AND CHOICE OF TECHNIQUES

the possible *perverse* (*or*, in other countries, *virtuous*) *link between capabilities and economic signals* in shaping the rate of diffusion of new technologies. This property, taken from an inter-country perspective, suggests, loosely speaking, the differential technological dynamism stemming - in the form of a differential behavioural incentive - from the very fact of being "rich" and "advanced".

Heading in the opposite direction, another property of technological diffusion places, so to speak, a "premium" on being "new" and "late". This property relates to capital-embodied technical progress and stems from the fact that, in this case, technological choices are associated with increases in productive ~~of~~ capacity or scrapping decisions. As regards the latter, they are generally based on the well known condition that the *total* unit cost on the "new" vintage of equipment must be greater than the *running* costs on old vintages.

Formally, at time t a machine of the vintage (t-s) will be scrapped only if:

$$\frac{b(t)}{L^*_t} + a\ (t).\ w(t) \leq a(t-s).w(t)$$

$$\text{with } b(t) = P_{kt}.\ K_t/Y_t.P_y$$

$$a(t) = N_t/Y_t$$

where t = time index, denoting also the vintages of the various machines

w = wage
N = labour inputs
K = capital input
P_k = price of the "machine"
P_y = price of final output
y = output
L^*_t = expected economic life of the new equipment (weighted with a discount factor).

The point is that an "old" producer (say someone who adopted best-practice equipment two "periods" ago) is stuck with a machine which is still economically viable even if it is not the best available. In his case, all acquisitions of new best-practice machines will be related only to a possible increase in productive capacity. Conversely, this is not the case of a new producer who will be able to utilize an entire stock of best practise equipment, provided that he has the capability of adopting and running it (and this is a crucial condition, as we saw in the discussion above). Th~~i~~us, in this case, "being new" provides, in a sense, a counter-mechanism to the cumulative processes which, taken alone, are a source of asymmetries and entry-barriers.[1]

The way we wrote inequality 1., above, allows us to consider at greater detail some other variables which affect the rate of diffusion of the new technologies. In order to do that, let us simply re-arrange it, and define a diffusion function (R) which we take to be growing in the difference between the running cost of the oldest equipment in use (t-s) and the total cost on the best one. Moreover let us assume exponential rates of change (so that for example $a(t) = a_o e^{\lambda t}$, where λ is the rate of change in the inverse of labour productivity, etc.).
Then

$$R = f \{w(t).a_o (e^{\lambda(t-s)} - e^{\lambda t}) - \frac{b(t)}{L^*_t}\}$$

First, the higher the rate of labour-saving technical progress, ceteris paribus, the higher will be the rate of scrapping and thus the rate of diffusion of best-practice equipment (that can be seen from the two exponential expression in brackets: their difference will increase with the increase in the absolute value of λ) Second, the higher the fall of the relative price of machines to

---

1) The reader may think, for example, of the case of steel where new producers (Japan, etc.) overturned the traditional pattern of advantage vis-à-vis traditional producers (e.g. Germany, USA, etc.).

output and the increase in the physical productivity of machines (expressed by b(t)) the higher the rate of diffusion.

Third, the rate of growth of wages, too, has a *positive* influence on the rate of diffusion, since, in a sense it "amplifies" the gains from the higher productivity on the latest vintage of equipment[1].

These properties are theoretically rather straightforward, although empirically important and worth a careful investigation. Another property is more counter-intuitive and relates to the role of technological expectations[2] as expressed by the L^*_t coefficient. That variable simply expresses the expectations on the economic life of the machine, jointly with the discount factor implicit in the actualization of future revenues. Let us neglect the second for the time being. As regards the former, so to speak, the "first order" expectations are essentially a function of the expected rate of technical progress in the near future as compared to the near past. The crucial feature is that any *expected acceleration* acts in the same way as an increase in the capital/output ratio, thus retarding the rate of diffusion. The opposite applies to an expected slow-down. If we take this point jointly with the first one, above, we come to the remarkable property that an expected acceleration of technological progress, especially when starting from a low rate embodies its own *retardation* factor. Conversely, the maximum rate of diffusion is likely to apply when the rate of technical progress is very high and begins to slow-down.

---

1) The second and third points, taken together, are clearly consistent with Sylos Labini's hypothesis that the relative price of machine to labour has an important effect upon the trends in average labour productivity. Cf. Sylos Labini (1984).

2) The property which follows was clarified by a discussion with José Cassiolato, whose contribution I want to gratefully acknowledge.

This mechanism has far-reaching implications in the sense that, in a broad historical perspective, it can help to explain one of the endogenous factors accounting for an initially slow diffusion of new technological paradigms (cf. electricity at the end of the last century, microelectronics in the post-war period, etc.) and a "snow-ball" momentum when the technology approachees its mature development.

Moreover, note that any increase of the rate at which the future is discounted (say, the expected real interest rate) induces a "myopic effect" which, ceteris paribus, slows down the rate of diffusion of the "new machines", and vice versa for a fall in that discount rate.

Another set of variables influencing technological diffusion relate to:

a) the industrial structures
b) the competitive patterns
c) the nature of the product-markets.

We consider them in turn.

The first set of variables is probably the most familiar in industrial economics, which has often tried to test what is ill-defined as the "Schumpeterian hypothesis", namely the idea that innovative activities are positively correlated with firm size.[1/] In so far as diffusion represents an innovative process for the adopting firms, then this area of investigation is directly relevant for our discussion here. Briefly, the most recent analyses suggest that (i) there generally are non-decreasing returns to scale in the innovative activity and sometimes increasing ones (cf. Soete (1979); (ii) there is a high sector-specificity of the relationship between innovativeness and size (cf. Townsend (1981)), so that, for example the contribution of big firms to innovation is overwhelming in process industries

---

1) On this issue see for two opposing view, Scherer (1980) and Soete (1979).

(chemicals, etc.) and consumer durables, while small firms play an important role in electrical and electronic instruments, machine tools, etc.; (iii) as regards the proper diffusion patterns, by and large, it appears that the rate of diffusion is positively related to firm size (cf. Mansfield (1968) and (1977), Davies (1979)).

The reader, however, must be warned *against* interpreting this evidence in a *causal* sense, for example drawing the conclusion that a simple increase in average firm size will increase the speed of diffusion, etc. It may, but it also may not. The reason is rather straightforward. What most tests show is some kind of *structural picture* (say, in a cross-firm intra-sectoral analysis, or, more often, in a cross-sectoral one)and some *structural regularities*. However, firm sizes (and by implication the degrees of industrial concentration) are themselves a *result* of historical processes of innovation, technology - based rivalry, etc.: it may well be, for example, that a firm is big *because* it has systematically been a quick innovator/adopter and *not* vice versa. In other words, size ~~the~~ and concentration have to be properly treated as *endogenous variables*.[1] Moreover, it is worth stressing that any possible relationship between size and innovativeness depends in crucial ways upon the degrees and forms of *appropriability* of technological advances (and, therefore, to repeat, is highly sector-specific and technology-specific). Empirical investigations attempting to formally disentangle the effect of lato sensu innovativeness upon size and concentration from the effect of the latter on the former have still to come. Incidentally, one must notice in this respect that the analysis based on micro-evidence, questionnaires, non-parametric variables, can be, for the time being, a precious help in identifying the "true" impact of size upon innovation/diffusion (e.g. in terms of differential technological capabilities, better "information", greater financial possibilities, easier availability of skills, possibility of diversifying risks, etc.) Clearly, these are all variables whose relative importance deserve a careful empirical investigation.

---

[1] For arguments on these lines, cf. Nelson and Winter (1982), Dosi (1984), Momigliano and Dosi (1983).

A second important set of variables certainly affecting the pace and possible also the direction of technological innovation and diffusion relates to the *prevalent competitive patterns* in each industry and product-market. Here it is important to introduce, first, some theoretical remarks. As known, the traditional theory operates some kind of *reduction* of the behaviours of firms in terms of a supposedly unique principle of maximization. This is true also for "mainstream" diffusion models, whereby the retardation factors in the observed diffusion patterns are behavioural based on maximization either in conditions of imperfect information and or within inter-temporal Cournot-Nash equilibria. Throughout this paper we have suggested, on the contrary, that a powerful set of retardation factors relates to differential *capabilities* of and differential *incentives* for each agent. In addition, we believe that even the assumption of uniformity of the "rationality principle" of all agents (in terms of maximization) is analytically misleading. As thoroughly argued by Nelson and Winter (1982), under the conditions of uncertainty, irreversibility, multi-level strategic inter-actions, which characterize the economic system, the most adequate representation of behaviours is in terms of *routines* and *meta-rules* (i.e. *bounded* and, possibly, *multiple* forms of rationality) which, we claim, depend also on the features of the context (in terms of nature of the prevailing technologies, patterns of interactions between the agents, macroeconomic and "macrosocial" conditions, etc)[1].

For our discussion here, there are two important consequences. First, the rate and direction of innovation/diffusion depends, other things being equal, upon the prevailing *forms of rationality* of any one industry/country at any one time. Anecdotically, the reader is invited to think ~~to~~ of the differences in the pace of innovation/diffusion between, say, England and Japan. Certainly part of the explanation rests in structural factors (capabilities, incentives, etc.). However, part of it

---

[1] We argue this point at greater depth in Dosi and Orsenigo (1984).

rests also in the dominant forms of "rationality" of the agents, their "metal-rules" concerning innovation, change, growth, etc.[1]

Second, the forms of "rationality" jointly with structural conditions, (such as the nature of the product-markets, the relationship with the suppliers, the patterns of vertical and horizontal integration, the modes of appropriation of technological advances, the scope for economies of scale, the elasticity of demand, etc.) determine the dominant *forms* of *inter-action between the agents*, the forms and intensity of oligopolistic *rivalry*, and, through that, the intensity of the "stick-and-carrot" incentives that competition provides for innovation/diffusion.

Both points are very important and might deserve some further illustrations. For example, industrial economics - in the broader sense - should be able to answer to questions like: what is the intensity of oligopolistic rivalry? When collusion is likely to emerge? Will collusion apply only to price/quantity adjustments or also to the rate and direction of technological advances? Is the intensity of competition positively associated with the rate of technological advances?, etc.

Differences in the *structures* go some way in explaining these differences in *conducts* . However, when multi-level strategic inter-actions are present (such as in all oligopolistic markets), conducts cannot be univocally deducted from structures. If anything, the degrees of behavioural freedom the agents can enjoy - given any one configuration of structural conditions- are filled by *institutional* regularities, in the forms of prevailing "rationalities" and dominant forms of interaction. On the ground of this argument, we suggest the following hypothesis: given any one set of structural (technological, etc.) conditions, the rate of innovation/diffusion is also a function of the

---

1) Traditionally, one reduces *ex post* these differences to differences in the inter-temporal rates of discount, distributions of subjective probabilities in relation to risk, etc., on the ground of a common maximizing behaviour. This procedure, however, as we argue in Dosi and Orsenigo (1984), seems to us scientifically very weak.

dominant forms of rationality of the agents and their patterns of interaction. In many ways, these forms of rationality and interactions are part of what the French call "regulation"[1], meant here to include also the fundamental rules of behaviour of the main socio-economic agents and the institutional forms of coordination between them. In this sense the prevailing forms of "regulation" (in the French sense) shape/hinder/favour the patterns of diffusion, according to the "matching" or "mis-matching"[2] between them, the nature of the prevailing technological paradigms and the general macroeconomic and macrosocial conditions. So, far example, will "more competition" induce faster rates of diffusion? As an empirical statement one may reasonably suggest that it often does. However, whether it occurs or not depends, for example, on the prevailing "adjustment rules" of the agents: it could well be, for example, that simply "more competition", leaving the overall conditions of "regulation" unchanged, may mean more "shortsighted" and more risk-adverse behaviours, and, thus, a lower long-term rate of innovation/diffusion.

As third set of variables effecting the patterns of diffusion relate to the nature of product/markets and more generally the links user-producer. Clearly, the evolution over time of final demand and of input-output relationships between sectors is a source of stimuli to technological change in general, including, of course, technological diffusion. A part of the discussion above concerned the effect "downstream" of technological advances occuring, so to speak, "on the supply side". Conversely, one must consider here also the "inducement effects" upon any one pattern of technological diffusion going "upstream" from demand to the supplying sectors. In general terms this set of demand-related stimuli is complementary to the other one, related to relative prices and income distribution - discussed above: jointly they form those "market signals" which contribute to explain the "endogenous" and "induced" part of technological progress.

---

[1] cf. the contribution of B. Coriat to this same IPEA project. Some discussion can also be found in Dosi and Orsenigo (1984). A bibliography is in Lipietz (1984).

[2] For this concept see also Perez (1984).

Let us suggest the following propositions:

(i) Other things being equal, the rates of "normal" technical progress and of diffusion of any one innovation (or cluster of innovations) is positively affected by the rate of growth of demand. We referred to it above as the "Schmookler effect". As such, it operates in two ways. First, sectors/technologies/products characterized by relatively high rates of demand growth also signal relatively high profitabilities and perspectives of expansion for the successful innovators, thus stimulating innovation/diffusion. Second, high rates of growth of demand, in absolute terms, are associated with high investments and, thus, high possibilities of adoption of best-practice equipment.

(ii) The nature and in particular the technological sophistication of demand (either final or, even more so intermediate demand) is positively correlated with both the technological levels and dynamism of the supplying sectors. We could call this as a "filière effect", in the sense that this relationship, which *runs both ways*, tends to organize the economic system around *clusters* of technologies and sectors linked by strong input/output and/or technological/informational flows and complementarities.

(iii) Each pattern of demand, with its rate of growth, the variance in that rate and the degree of uncertainty about both the expected growth and the "preferences" of the customers, jointly define specific *trade-offs between manufactuging flexibility and economies of scale and between decisional flexibility in the future and irreversibility of present technological decisions*.

The implications of the first two propositions are rather straightforward: the rate of innovation/diffusion in any one sector, *ceteris paribus*, will be positively affected by (a) the relative rate of growth of demand (as compared to other sectors), (b) its absolute rate of growth, (c) the intensity, completeness and technological sophistication of inter-sectoral linkages, (d) the performance requirements (in terms of quality, reliability, etc.) of final demand. The consequences of the third proposition are worth some further comment. Let us first consider the trade-off between manufacturing flexibility and economies of scale. The nature of this trade-off is generally defined by the nature of the fundamental technology in use (i.e the "technological paradigm"). Take the example electromechanical technologies for metal-working: higher efficiency of production (stemming from standardization, economies of scale, etc.), generally associated with "taylorist" and "fordist" principles of organization of production, is also generally correlated with higher degrees of inflexibility - in terms of acceptable variance in production runs and mixes. Figure 5 illustrates such a case. Suppose that the line AA represents the technical relationship between "normal" average total unit costs (c) and rates of throughput ($\dot{d}$), while the line FF represents the corresponding relationship between unit costs and degrees of flexibility (F), say, approximated by the standard deviation in the rate and mixes of throughput which does not significantly increase "normal" unit costs. One can generally expect that one of the fundamental dimensions of technical progress *along any given* technological trajectory (i.e. on the ground of an *unchanged* technological paradigm) is the increasing exploitation of economies of scale, economies of standardization, etc.[1] Thus, any increase of the flexibility requirements due, for example, to increasing uncertainty about the levels and composition of demand, indirectly represents a retardation factor of technological innovation/diffusion *within a given technological paradigm*, in so far as technical advances are also scale-based. So, far example, one may speculate that the depression of the '30s acted as a retardation factor on the process of innovation/diffusion along the electromechanical

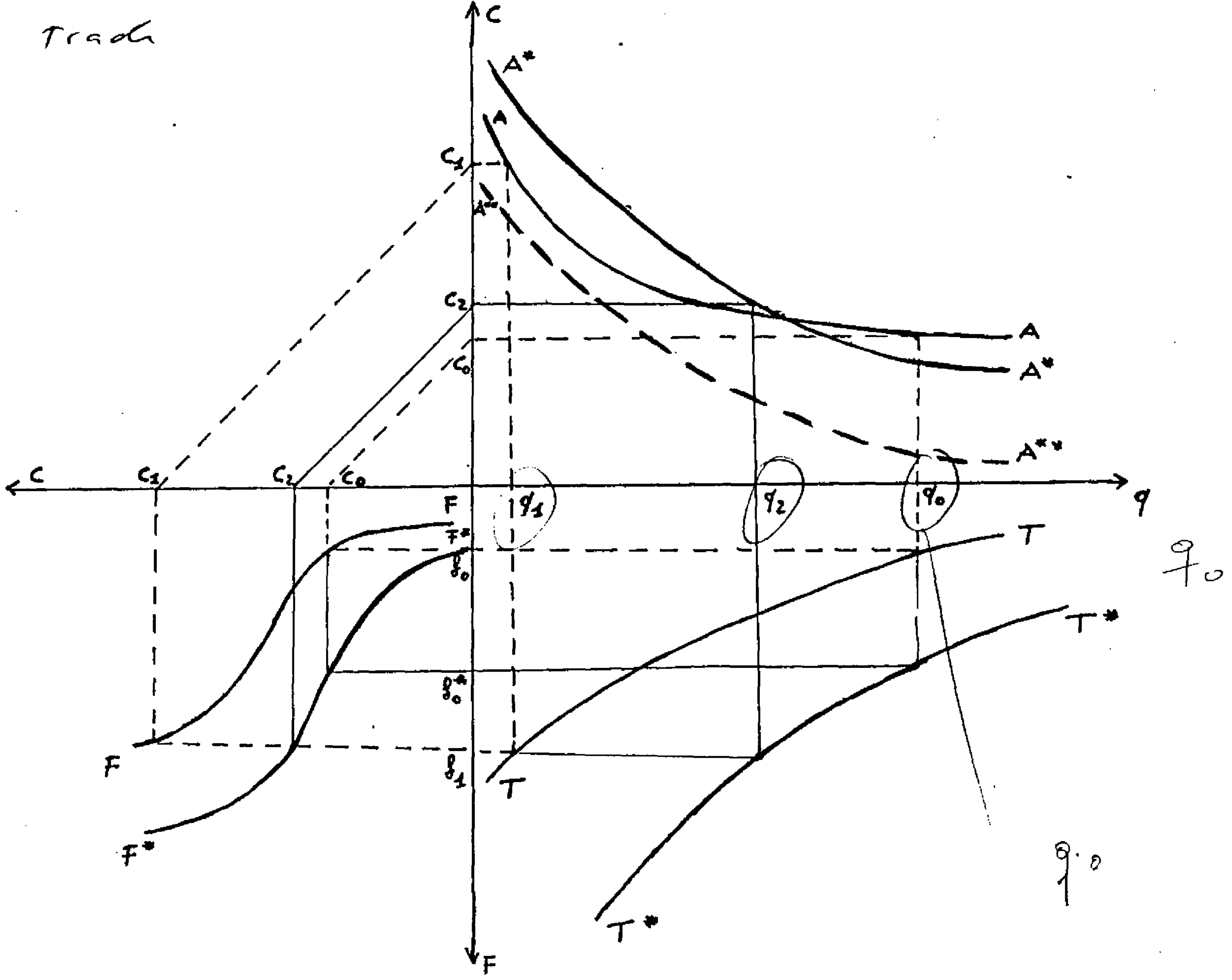
---

1) On this point, cf. Nelson and Winter (1977)

Fig. _: made-off between flexibility and economies of sc.e

FIGURE 5: THE TRADE-OFF BETWEEN FLEXIBILITY AND ECONOMIES OF SCALE

FIGURE 5 The Trade



taylorist/fordist trajectory, etc. However, different technological paradigms embody different trade-offs between flexibility and scale. Suppose for example that, in figure 5, the line A*A* represents the relationship costs/quantities for a new (say, the electronics-based) paradigm, while the line F*F* is the corresponding relationship flexibility-costs. Thus, the trade-off quantity/flexibility is TT for the "old" technology and T*T* for the "new" one[1]. Now, consider again an increase in the "desired" flexibility. Remarkably, this is likely to have two effects: first, it is likely to hinder "normal" technical progress/diffusion along the "old" technological trajectory while, second, fostering innovation/diffusion in the new technological paradigm. Interestingly, this may be so even in those cases whereby the "new" techniques are not unequivocally superior to the old in purely economic/technical terms[2]. Figure 5 illustrates one of such cases. Suppose with start from production runs equal to q_0, normal total costs at C_0 and a degree of flexibility f_0. Now, say, the economic crisis, an increasing uncertainty about consumers' demand and rivals' strategies, etc. increase the required flexibility of production, from f_0 to f_1. On the ground of the "old" technological paradigm, this would mean very short production runs (q_1) and very high costs (C_1). The "new" paradigm (e.g. electronics -based automation) changes the nature of the trade-offs, allowing for example the required flexibility to be achieved at throughput q_2 and unit costs C_2. Moreover, we suggest, the higher technological opportunities of the new paradigm (with its scope for learning, decreasing costs of capital equipment, etc.), in the long-term will shift the techno-economic relation between costs and quantities, say, down to A**A**. The reader, perhaps, should take this as something more than ~~an~~ an hypothetical example and ~~consider it as~~ a highly simplified illustration of some features of the transition from an electromechanical (taylorist/fordist) pattern of automation to a new electronics-based paradigm.

---

[1] This example owes a lot to the discussions with B. Coriat on automation in general and, in particular, the car industry.

[2] This is vaguely similar to the example of two intersecting wage-profit frontiers given in figure 4. B. Coriat suggests that this is precisely the case of contemporary automation in the car industry.

Let us consider now the other relationship between future flexibility of decisions and the degree of irreversibility of present technological choices. Clearly, outside the timeless world of economic textbooks, any technological choice at any one time entails, to different degrees, *irreversibility*, and, thus, a restriction on the behavioural degrees of freedom at a future time.[1] The most obvious example are the irreversibilities associated with investment decisions on fixed equipment. However, at least equally important, *all* strategic decision about technologies, products, research, etc. involve irreversibilities in that they involve choices about "trajectories", fields of expertise, patterns of management and production, etc. If this is so, it is straightforward that the higher the uncertainty about future technological development, patterns of demand, etc. the higher will be also the retardation in the diffusion of any new technological paradigm(s). In other words, the higher the uncertainty, the higher the importance - as a behavioural rule - of the *future* degrees of freedom which different present options allow.[2]

These considerations, jointly with those other ones, above, about *technological expectations*, highlight the paramount importance of the overall *technologic regimes* and *modes of regulation* (in the French sense) in shaping the patterns of diffusion of new technologies. Other things being equal, one may expect the rate of diffusion to be higher the higher is also the *consistency* between (a) patterns of demand, (b) patterns of investment around the new technologies, (c) mechanisms of coordination (in terms of technological and productive decisions) between firms and between sectors, (d) mechanisms of formation of expectations. Not surprisingly, in the process of transition between clusters of different technological paradigms, the process of search of new technical/economic/socio-institutional set-ups, the uncertainty is highest and, with that, also its "retardation effect". Conversely, the smoothest and fastest diffusion is likely to be achieved when a sufficiently developed new regime (of technologies,

---

1) On this issue, cf. the stimulating contributions by Amendola (1984) and Parrinello (1983).

2) *Ibid*.

institutions, firms, behaviours) induces a "snowball effect": the behavioural and tecnological consistency between different parts of the system, at that point, provides, as it were, the "coordinates" for the formation of expectations and foster the commitment of individual agents to the new technological paradigms.

Finally, a complex and very important set of factors affecting the rate and direction of technological innovation/diffusion relate to socio-institutional factors in the broader sense. In particular two clusters of factors are worth mentioning. First, the nature of labour proccesses and the patterns of industrial representation and conflict may often play a crucial role in the choice between different technological set-ups and even induce the development of particular modes of productive organization and trajectories of progress. Second, the nature of public policies is crucial as well, with regards to both microeconomic policies (incentives, financial transfers, R&D, competition policies, trade policies) and macroeconomic ones (income distribution, rates of macroeconomic activity, development of infrastructures, etc.). It is impossible to discuss here with adequate detail these two broad clusters of factors. With reference to the first one, we refer to the contributions of B. Coriat and H. Schmitz to this same research project. As regards the second, some introductory and partial remarks can be found in another work of the author.[1]

However, it is important to mention that the questionnaire for the empirical investigation, annexed to this Report, does consider those variables related to social and institutional factors which may affect the rate and direction of technological innovation/diffusion.

Technological Diffusion and Patterns of Economic Change

In the first part of this Report, we focused primarely on the determinants of intra- and inter-sectoral diffusion of innovation. Some of these determinants, we saw, are behaviourally rooted in the patterns of competition, and the strategic behaviours of the firms in terms of cost reductions, product imporvements, etc. In this respect, the motivation and the incentive to the introduction

---

1) cf. Dosi (1984a)

adoption of innovation directly corresponds to expected effects such innovations may have on economic variables. However, the impact of the innovative process quite often goes well beyond the intended consequences and is both a consequence and a source of unitended changes in the main performance variables of the economic system, in terms of production processes, nature of the inputs and outputs, input coefficients, industrial structures, etc. Thus, it is worth considering the whole set of effects (both intended and unintended ones) of innovation/diffusion, in a multi-sector framework, in order to discuss

a) the evolving thread of inter-sectoral relationships
b) the change in the technical/economic variables of each sector (e.g. - input coefficients, outputs, etc.)
c) the effect upon industrial structures.

Clearly, this discussion is a fundamental medium term linking the proper microeconomic level (that level at which individual decisions are taken and competitive inter-actions occur) with the strict macro level (which embodies, among other things, the net macroeconomic balance between the dual effects of technical change as input-saver and demand-generator, the prevailing nature of the organization of production and consumption; the general morphology of the economic structure). First, as regards the set of inter-sectoral relationships, technical change in a sense organizes the hierarchical order of (i) input-output interdependences, (ii) inter-sectoral technological flows, stimuli, bottle-necks, opportunities. In doing so, it also affects the inter-sectoral location of the main impulses to change and the contribution each sector is making to macroeconomic demand formation. More specifically in relation to the set of microelectronics technologies, one can state the following hypotheses:

a) Along with the incorporation of microelectronics into previously electromechanical capital goods and equipment, the main source of change is located at the interface between information processing, environment control (in terms of pattern recognition; sensors; detectors of positions and physical porperties;

etc.) and mechanical movements.

b) There is a complex balance between elements of continuity and "revolution" in the patter~~s~~n of microelectronics-based technical change as compared to the previous electromechanical trajectory of automation[1]. On the one hand, the "revolutionary" element relates, obviously, to the radical newness of the microelectronics paradigm (the new "heuristics", knowledge, etc. it embodies). In practical terms, that new paradigm involves also for the first time varying degrees of self-adjustment, real-time feedbacks, system coordination between separated mechanical operations. On the other hand, the fundamental ground for continuity rests in the pattern of pre-electronics automation. In a sense, the fundamental dimensions of the traditional trajectory (in terms of labour-saving, optimization and control of productions flows, repeatability of operations, etc.) are modified and strengthened within the microelectronics-based paradigm. A relevant consequence in terms of capabilities of innovation/adoption of the new technologies is that the differential success of campanies and countries in managing the new technologies crucialy depends on the capabilities in both "traditional" electromechanical automation and electronics/information processing/system management.

c) As regards the inter-sectoral loci of macroeconomic demand formation, that same interface between electromechanical technology, electronic technologies and information-based infrastructures is likely to become the "center" of capital accumulation. Conversely, the interface between electronics technology and both "traditional" and "new" consumer durables is

---

[1] On this issue of "reform" vs. revolution, cf. Erber (1983) and Pavitt (1984a).

likely to be a crucial factor in final demand formation.

Contextually to these trends in the overall industrial structure, <u>each industry</u> and <u>each vertically integrated sector</u>[1] change in its technical and economic performance. Clearly, every product innovation in the equipment producing sectors brings about a change in the "physical" productivity of "machines" in the user-sectors; every process innovation in equipment production affects relative prices and, thus, also the capital/output ratio for the users; most innovation induce changes in the labour coefficients, etc.

Therefore, some of the fundamental indicators of the effects of technical progress have to be detected within the trends in the technical/economic variables characterizing each industry and vertically integrated sector.

The main indicators to be investigated are:

a) Labour productivity;

b) Degrees of mechanization/automation of production (in terms of capital/labour ratios);

c) Degrees of capital intensity (in terms of capital/output ratios). In turn, this indicator is the joint result of two factors, namely, the "physical" productivity of fixed equipment and the relative price of "machines" to output;

d) The ratio between fixed and circulating capital;

e) The actual exploitation of and the scope for economies of scale, of both static and dynamic kind, and their functional location (at the level of the plant, the firm, etc., in production, in R&D, in commercialization, etc.);

---

1) That is the sub-system of activities directly or indirectly activated by any one item of final demand. For a discussion of the concept and an interpretative use in terms of economic dynamics, cf. Pasinetti (1981), Siniscalco (1983).

f) The nature of the output (including its performance features, quality, etc.);

g) The varying degrees of production flexibility and, often, the nature of the trade-off between flexibility and economies of scale.

As regards specifically microelectronics technologies, let us suggest the following substantive hypotheses:

(i) Microelectronics has and - even more so - will have a strong labour-saving effect (in the simplest sense of decreasing the unit labour coefficients).

(ii) This effect already started manifesting in the most recent years. However, the observable trends in labour productivity in the late 70's/early 80's are an effect of both electronics-based technical progress and more "classical" processes of rationalization and increasing mechanization of production.[1]

(iii) The effect of electronics-based technologies is likely to be very wide-spread across sectors but rather uneven in terms of sectoral impact. More precisely, in the *medium* term it is likely to be greater in those sectors which provide an easier opportunity of adoption given the already mechanized/automated structure of production (including a good part of consumer durables). Conversely, in the *long* term, the impact might be greater in those sectors wherein "classical" automation was intrinsically difficult or partial in scope but "intelligent" (electronics-based) automation may be feasible (this set includes some of the "traditional" sectors)

---

[1] Note that this statement does not conflict with the evidence on productivity slow-down in the 70's-80's. On the contrary, once allowance is made for the impact of slower *income* growth upon productivity growth (the "Verdoorn-Kaldor law"), the *increasing labour-saving*, ~~the~~ clearly emerges. An apparent exception are the US. The possible explanation of this phenomenon are, however, outside the scope of this paper.

(iv) Remarkabl~~e~~y, there is evidence that in those sectors which are more strictly electronics-based (e.g. computers, etc.) technical progress is not only labour-saving but also strongly <u>capital-saving</u>[1] in that sense diverging from an apparent aggregate increase in capital/output ratio in the majority of the manufacturing sector in central countries.[2] It is tempting to speculate that, in the long-term, the capital-saving effect of electronics will "filter-down" to the whole set of manufacturing industries. This is likely to be so f~~a~~or three reasons. First, the process of diffusion of electronics-based capital goods is likely to induce learning economi~~c~~es, economies of scale, etc. in their own production, thus decreasing, ceteris paribus, the relative price of machines to output. Second, there is a similar process of learning/ cumulative improvements on the side of the users. Third, the same process of incorporation of electronics into capital equipment often implies product-innovations in the "machines" which increase their physical output.

(v) Within the electronics-based trajectories of technical progress the position and nature of the trade-offs between flexibility and efficiency is significantly changed in the sense that (a) the overall flexibility of production (in terms of changing product-mixes, etc), is likely to increase for any <u>given</u> rate of output, and, conversely, (b) the efficiency of production processes is likely to increase also at low rates of output (which historically

---

[1] Cf. Soete and Dosi (1983)

[2] See the results of the OEC~~B~~D Project on "New Industrial Structures". However, it must be noticed that the apparent trends toward increasing capital/ output ratios is uneven between countries. Moreover it may well be overestimated, due to the underestimation of the amount of accelerated scrapping occurred especially after 1973.

have always been chosen for highly variable/flexible/ small batch production). Which one of the two effects is greater is clearly a sector-specific and technology-specific feature.

(vi) Another effect of microelectronics-based technologies is likely to be toward the decrease in the ratio of circulating capital to output and whenever the capital-saving impact is not too strong, also, in the ratio of circulating to fixed capital. This is clearly due to the new possibility of optimising throughputs and minimizing stocks (inventories).

Finally, all the above-mentioned trends have obviously a profound impact upon industrial organizations and in particular on:

a) firm - and plant - size
b) degrees of concentration
c) locational patterns of production
d) patterns of strategic inter-actions among firms and between the firms and the product-markets
e) degrees of vertical and horizontal integration, product diversification, etc.

We have already mentioned in the first part of this Report ~~in another contribution ("Some notes on technological diffusion")~~ that industrial organizations should be properly considered as endogenous to the process of technical change and dynamic competition. This should even be clearer from the foregoing discussion: in a sense, the evolving patterns of industrial organizations is simply another feature of (a) different degrees of success/failure in the process of innovation/diffusion and (b) the nature of production processes (in terms of scope for dynamic and static economies of scale, trade-offs between flexibility and efficiency, etc.).

Again, with reference to the microelectronics-based technologies, let us suggest the following hypotheses:

(i) Generally, the transition between two major clusters of technological paradigms (such as also that from electromechanical to electronics-based paradigms) implies a *partial disintegration* of old oligopolistic structures and the tendential formation of new ones. In many ways, how radical is the distruption depends on how "revolutionary" is the technological transition and how different are the expertise, knowledge, production processes, etc. in the new paradigm via-à-vis the old one. As we suggested above, it appears that "revolutionary elements" are deeply associated with other more incremental and cumulative ones. This manifests itself also in terms of industrial organizations. While at the core of the technological discoutinuity (i.e. - in the semiconductor industry) the change in terms of entry/exit, market shares, leadership, has been dramatic, the more we move away from it the more we can observe *gradual* changes within a relatively stable pattern of industrial organization. So, within the broad cluster or electrical and electronics industries major entries occurred (especially semiconductor - and computer-related companies) and major changes in the ranking between the partecipants of this wide and loosely defined oligopoly. Remarkably, however, even at this level of proximity to the "revolutionary core", most of the participants to this international oligopoly are the old electromechanical leaders [1]. Yet further away, the penetration of electronics technologies in e.g. mechanical manufacturing is simply one of the factors of dynamic competition and modification of production processes (albeit a crucial one),

(ii) In the process of transition between the two techno-economic regimes (the electromechanical and the electronic ones) an important role is played by small and medium enterprises. This appears to be so far three reasons. First, there is a set of small ventures which we could term as "Schumpeterian": new firms discovering new market niches, developing

---

1) Cf. Pavitt (1984a).

new products, etc. Second, for the very nature of the new technologies, mentioned above, the changing trade-offs between flexibility and production efficiency allows a process of "Smithian" division of labour and specialization between different productive units. Third, as it happened in several industrialized countries (e.g. USA, Italy), an increased dualism in production organizations and labour markets was the strategic response to the levels of industrial conflict and institutional rigidity which developed in the oligopolistic sector of the economy. However, it must be stressed, we do not believe that the "central-italian pattern of development" is the dominant long-term trend. On the contrary, in our view, what we are witnessing now is the *search for a re-definition* of the *patterns* of *complementarity* between re-shaped oligopolistic structures and small specialized firms.

(iii) Contextually to this process, new patterns of *vertical* and *horizontal* integration are likely to emerge, organized around the exploitation of the synergies and interfaces between electronics and electromechanical technologies.

As already mentioned, these broad effects of technological change are part of a search of a new macroeeconomic and "macro-technological" patterns of production, accumulation and organization. In this sense, the study of the (intended and unintended) outcomes of technological innovation and diffusion are a necessary introduction to the appraisal of broad "macro" questions such as those related to the overall impact of technical change on employment, growth, forms of social organization, etc.

Some methodological remarks

On the grounds of the discussion undertaken above, we are going to suggest here some possible lines of empirical inquiry. Notably, the following suggestions still mantain some degrees of abstraction, in that they do not confront explicitely the problems of data availability, collection, elaboration, etc. The author does not possess any detailed and thorough knowledge of Brazilian statistical sources. The usefulness of what follows is meant to rest at two levels. First, it may help in outlining some of the relevant questions, which the research should try to answer. Second, it may represent some kind of yardstick against which the actual availability of data can be assessed. The present suggestions benefited a great deal from dicussions with the IPEA/CNRH staff and the other two external consultant to the project, Benjamin Coriat and Hubert Schmitz, and from seminars at COPPE - Rio de Janeiro; FUNCEX, the Institute of Industrial Economics of the UFRJ and especially from the comments of Fabio Erber.

Let us distinguish between three levels of analysis, namely

i) what we could call a "structural picture" of the sectoral patterns of diffusion
ii) the <u>determinants</u> of diffusion itself
iii) the sectoral and inter-sectoral <u>effects</u>

As we discussed above, the rates of diffusion of any new process/product/equipment, etc. depend on a set of factors which have to do with (a) the technological opportunity (i.e., in the broader sense, the "easiness" of technological advances), (b) the <u>capabilities</u> of the agents, relative to the various degrees and forms of appropriability, imitability etc; (c) the nature of economic signals and incentives related to costs, profitabilities, nature of product-markets, etc.; (d) series of environment pressures, lato sensu, ranging from the prevailing patterns of competition to the nature of industrial conflict, etc.

The fundamental point for our purposes here is that these features are technology-specific, sector-specific and country-specific .

There are two - deeply complementary - ways of disentangling these factors. First, a lot can be learned from the analogies and differences stemming from individual sector-studies. Over the past 20 years, several industrial studies have been undertaken in this area in Brazil: to my (limited) knowledge, they include works by J. Tavares, F. Erber, V. Pereira, A. Guimarães; P. Tigre, R. Tauile.

Second, an inter-sectoral picture can be gained from an analysis of the relative rates of diffusion in the Brazilian sectors of best-practice technologies, in relation to indicators of both industrial organization and technology-specific characteristics.

The data on imports of electronics-based capital goods, notionally available from SEI files, jointly with domestic production and sectors of use, may allow a first development in this direction. One of the novelties of such an undertaking, in my view, is that it allow rough[illegible] but still viable international comparisons. Thus, let us define, for example, the rate of diffusion in Brazil in sector i of, say, numerically-controlled machine tools as the percentage of such machines over the total investment flows in a certain period t, call it D_{iB}. Define the analogous measure for "central" economies as D_{iw}[1] Then, $d_i = D_{iB}/D_{iw}$ is the relative Brazilian rate which, in an inter-sectoral comparison, at least partly discounts for sector-specific and technology-specific opportunities of diffusion. Obviously, in practice it is rather hard to find appropriate measures for "best-practice" technologies. However, in my view, the relative rates of diffusion of electronics-based capital equipment is already a significant analytical step, relevant for all those sectors which have been and are significantly affected by capital-embodied electronics-related innovations. A "structural picture" of this kind implies als the identification of possible regularities in these relative rates of diffusion.

---

1) This measure can either be an average of Europe, USA, Japan or the actual rate in the "fastest" [redacted] economy.

Some of these regularities may be simply related to a priori taxonomies of the sectors (e.g. are these relative rates higher/lower is capital-goods vs. consumer-goods sectors? in electrical/electronics engineering vs. mechanical engineering? etc.) In this respect, useful hints may emerge also from an analysis based on Pavitt's taxonomy - related to the sources and uses of technology - which distinguishes between groups of industries called [1]:

a) supply - dominated (which includes most of the traditional industries, acquiring technological innovations via purchases of capital goods and materials from other sectors)
b) specialized-suppliers (such as machine-producers, etc.)
c) scale-intensive sectors (e.g. producers of bulk materials through continuous processes and producers of consumer durables through mass assembly)
d) science - based sectors (e.g. electrical and electronics sectors, many chemical areas, etc.)

Another useful taxonomic exercise can be based upon the results (which will be available in the very near future) of the research undertake at Yale University by Levin, Nelson and Winter on the opportunities and <u>sources</u>, <u>forms</u> and <u>degrees</u> of technological appropriability of innovations. Such a possible taxonomy, in a sense, can be tested against the intersectoral Brazilian data, thus trying to answer the question: are forms and degrees of appropriability of innovation regularly associated with retardation factors in international technological diffusion?

A third taxonomic categorization can be based on technical/economic data, whenever available, on the difference between electronics-based on "pre-electronics" technologies in terms of (a) labour-productivity and (b) capital/output ratios. Clearly, the underlying question - which rests on a choice-of-technique problem - is whether the "retardation

---

1) Cf. Pavitt (1984)

factors" are related to different structure of relative prices (and specially of machines to labour). In this sense, the second and third taxonomic exercices could help in distinguishing between a set of retardation factors based on appropriability/ relative technologies capabilities, etc. from another set based on economic incentives related to costs and profitabilities.

Conversely, another exercise may try to identify the possibles structural correlations with a series of variables related to lato sensu organizational and technological indicators of each industry.

Thus, one may test the existence and significance of the correlation between d_i (defined above) and sector-specific indicators such as:

- average firm size
- degrees of industrial concentration
- R & D intensity of the sector (in the "world" and/or in Brazil relative to the "world")
- ownership (MNCs/Brazilian, and private/public)
- average capital/output ratio in the industry
- skill-intensity of the labour force
- average capital/labour ratios (as a measure of the degrees of mechanization)
- degrees of import protection
- openness to the international market (as measured, for example by the ratio of exports to output)
- <u>relative</u> firm-and plant-size (via-à-vis, e.g. the USA)
- <u>relative</u> labour productivity (vis-à-vis, e.g. the USA)
- <u>relative</u> capital intensity and degrees of mechanization

It must be stressed that even the existence of significant correlations <u>cannot</u> be interpreted in a causal way: more correctly it provides the frame for a "photographic description" of the Brazilian industrial structure whose patterns must then be interpreted with a more detailed and more genuinely dynamic analysis. In this respect, it seems to me that the joint use of questionnaire techniques and case studies are of great importance. However, such a "structural picture" has a relevance on its own, in that it helps in identifying patterns and in differenciating between clusters of possible intervening variables (such as those related to the nature of the technologies as distinguished from those related to the forms of industrial organization).

Moreover, the very process of building the necessary statistical base for the exercise may yield interesting results on its own. For example: what is the "productivity gap" in terms of labour productivity vis-à-vis OECD countries? Are these sectoral gaps associated with (i) capital-intensities - in terms of relative capital-output ratios, (ii) degrees of mechanization/ automation - in terms of capital-labour ratios, (iii) degrees of technological dynamism, as measured, for example, in terms of relative rates of diffusion?[1]

On the grounds of a "structural picture" of the kind outlined above, it is obviously crucial to investigate the causal patterns yielding such an outcome. As already mentioned, in my view, case-studies and questionnaire techniques are very useful for this purpose. More precisely, only case-studies can provide a genetic/historical reconstruction of a particular technological development, the thread of inter-actions between the economic actors, the forces at work at any point in time, etc. On the other hand, a questionnaire methodology, in a sense, represents

---

1) It may be be worth mentioning that in an analysis undertaken on OECD countries (cf. Dosi, Pavitt and Soete (1985) we found a strong correlation between labour productivity gaps, on the one hand, and (i) degrees of mechanization and (ii) degrees of innovativeness, on the other hand, but no correlation with relative capital intensities. That is to say, there seem to be no evidence of significant processes of "static" substitution of the neoclassical type.

Clearly, there are formidable problems in comparing absolute levels of productivity between countries. However, [redacted] statistical data on 3 - and 4 - digit sectors may already provide an impression of the orders of magnitude. Morover, a research, currently underway at FUNCEX, Rio de Janeiro, on unit prices may provide very useful hints in the direction of a procedure somewhat similar to the "double-deflation" familiar to time-series analysis.

a crucial link between the more aggregate structural picture and the individual cases, in that it provides the elements for inter-sectoral and inter-product comparisons on the causal variables at work. The kind of questionnaire I suggest - of which a prototype is outlined in Annex II - has a semi-parametric form, in the sense that quantitative informations are collected jointly with quantitative ones ("how would you rank the importance of .....?") One of the fundamental aims of such a technique is to separate-out the relative importance of the determinants of innovation/ diffusion which relate to:

(a) broadly defined technological <u>opportunities</u>, stemming from advances in scientific knowledge/advances in other sectors/advances in other countries;
(b) a set of variables linked with the technological <u>capabilities</u> of the actual/potential innovators;
(c) the nature of <u>economic incentives and obstacles</u>, and, more specifically within this set of variables, (i) the influence of costs, relative prices, etc. and (ii) the role of product-markets, etc.;
(d) the possible influence of the <u>forms</u> of <u>industrial organization</u> on national and international level (including firm size, nationality, patterns of international competitions and forms of technological appropriation, etc.);
(e) institutional and labour relations.

The important point is that the joint use of inter-sectoral "pictures", microeconomic questionnaire and case-studies allows a <u>mapping</u> of necessary and sufficient conditions, behavioural determinants and sectoral outcomes of the patterns of innovation/ diffusion. So, far example, one should ideally be able to identify the sectors or clusters of sectors where the relative rate of innovation/diffusion is higher/lower (vis-à-vis the "frontier" countries) and then answer to questions like: Are there common determining factors which explain this differential patterns? Have they got to do with capabilities, forms of technological appropriation, economic incentives, patterns of demand, etc.?

Finally, a questionnaire technique may usefully supplement the more aggregate set of information on the effects of innovation/diffusion, a~~h~~lready discussed in the second part of this Report. ~~"Technological diffusion and patterns of economic change~~". The set of effects discussed there relate, lato sensu, to the evolution of the domestic economic structure and performance. Here it is important to mention another set of effects which relate to international competitiveness. In particular, it seems fundamental to assess the relative impact of cost- and price-related variables as compared to innovation-related ones. In another study on the trade patterns of OECD countries[1] we find that the variables related to technological change and capital accumulation dominate upon short-term adjustment in costs, prices, exchange rates as explanations of the levels and changes in the partecipation of each country to international trade flows. The test of a similar hypothesis for a country like Brazil would obviously have important implications also on a normative level.

For the time being let us neglect the impressive difficulties one would face in the practical collection of the appropriate date and focus on the "ideal" structure of such a test.

Let us define the following variables, for each industrial sector, i:

X_i = An export measure (say, the Brazilian share on world exports, in value)

T_i = A measure of technological level - we would suggest it To be a sector-specific compound index capturing things like, say, the relative rate of diffusion of best-practice technologies, the relative intensity of technician/engineers/scientists, the relative R&D intensity, etc. (all compared with one or a set of "central" countries);

K_i = The relative degrees of mechanization (as expressed by capital/labour ratios)

π_i = The relative labour productivity

---

[1] Cf. Dosi, Pavitt and Soete (1985).

N_i = T~~t~~he relative capital intensity (as expressed by the capital/output ratios)

W = T~~t~~he relative wage rate (in, say, US $)

M = T~~t~~he degree of "nationalization" of the considered Brazilian sector

P = T~~t~~he effective export subsidy (and/or other measures of institutional support)

Ideally, a test should take the following form.

$\dot{X} = f\ (\dot{T}$

$\dot{K}$ or, alternatively, $\dot{\pi}$

$\dot{N}$

W at the initial time

$\dot{W}$

M and $\dot{M}$ or ΔM

P and $\dot{P}$ or $\Delta P)$

w~~W~~here the dots are rates of change and Δ ... are variations.

Our a priori expectations on the signs would be the following:

$\dot{T}$: +, very strong

$\dot{K}$ and $\dot{\pi}$: +, very strong (with high multicollinearity between T and K, on the one hand, and π, on the other)

$\dot{N}$: - , weak (in other words, contrary to neoclassical expectations, the process of development should bring about some <u>fall</u> in the <u>relative</u> capital intensity, with a favourable effect on trade)

W: - , strong (in other words, the <u>absolute</u> wage gap brings about some kind of <u>structural buffer</u> of competitiveness which is exploited through the whole period of industrialization)

$\dot{W}$: ?, insignificant, either way (that is not to say, of course, that it does not have an influence on <u>cyclical</u> competitiveness but that it not affect the long-term trend)

M: ?

P: +

Summarizing, one would expect a dominant role of technological upgrading and capital accumulation upon short-term mechanisms of adjustment, starting from a positive of potential structural competitiveness stemming from a wide wage-gap, which is in a sense, "eaten up" in the process of industrialization and growth. A feasible technique for testing could be a pooling of the i - sectors. Moreover, again on rather ideal level, the excercise could be repeated on the ground of vertically integrated sectors, thus accounting for the levels and variations in the variables on the right-hand side (the "independent" variables) in their direct and <u>indirect</u> impact (via input-output flows).[1]

Needless to say, the empirical difficulties are enormous. In this respect, the foregoing suggestion may simply represent the clarification of a theoretical hypothesis for discussion. This, I believe, already has some analytical usefulness.

---

1) For a seminal use of this methodology for competitiveness analysis, see Momigliano and Siniscalco (1984). On the Brazilian case, see J. Tavares (1984).

Bibliography

L. A. Brown (1981), *Innovation Diffusion. A New perspective*, London Methuen.

R. Camagni, R. Cappellin and G. Garofoli (1984) (eds.), *Cambiamento Tecnologico e diffusione Territoriale*, Milano, Franco Angeli.

P. A. David (1975), *Technical Choice, Innovation and Economic Growth*, Cambridge, Cambridge University Press.

P.A. David and T.E. Olsen (1984), *Anticipated automation: a rational expectation model of technological diffusion*, Stanford, Stanford University, mimeo.

S. Davies (1979). *The Diffusion of Process Innovations*, Cambridge, Cambridge University Press.

G. Dosi (1984), *Technical Change and Industrial Transformation. The Theory and an Application to the Semiconductors Industry*, London, Macmillan.

G. Dosi (1984a), *Economic Signals in a Changing World. Some notes on innovation, comparative advantages and growth, and some policy implications*, Brighton, SPRU, University of Sussex, mimeo.

G. Dosi, K. Pavitt and L. Soete (1985), *The economics of innovation and international Trade*, Brighton, Wheatsheaf, forthcoming.

G. Dosi and L. Orsenigo (1984), *Rules, institutions and market processes in the theory of Technical change*, Brighton, SPRU, University of Sussex, mimeo.

F. Erber (1983) *Microeletronica: reforma ou revolução?*, Rio de Janeiro, Instituto de Economia Industrial, UFRJ, discussion paper.

C. Freeman (1974), *The economi~~e~~cs of industrial innovation*, 2nd. ed.: London, Francis Pinter, 1982.

C. Freeman (1984, (ed.), *Long Waves in the World Economy*, 2nd. ed., London, Francis Pinter.

C. Freeman (1984a) (ed.), *Innovation, design and long cycles in economic development*, London, Royal College of Arts.

T. Hagerstrand (1967), *Innovation Diffusion as a Spatial Process*, Chicago, Chicago University Press.

N.M. Hansen (1977) (ed.) , *Growth Centers in Regional Economic Development*, New york, Free Press.

N. Ireland and P. Stoneman (1983), *Technological diffusion, Expectations and Welfare*, Warwick, Warwick University, mimeo.

D. Landes (1969), *The Unbound Prometheus,* Cambridge, Cambridge University Press.

A. Lipietz (1984), *Accumulation, crises et sortie de la crise: quelques reflexions methodologique autour de la notion de 'regulation'* Paris, CEPREMAP.

E. Mansfield (1968), *Industrial Research and Technological Innovation: An econometric analysis*, New York, Norton.

E. Mansfield et al. (1977), *The Production and Application of New Industrial Technology*, New York, Norton.

S. Metcalfe (1983), "Impulse and Diffusion in the Study of Technical Change", in Freeman (1984).

F. Romigliano and G. Dosi (1983). *Tecnologia e Organizzazione industriale internazionale*, Bologna, Il Mulino.

L. Nabseth and G. F. Ray (1974), *The Diffusion of New Industrial Processes*, Cambridge, Cambridge University Press.

R.R. Nelson and S. Winter (1977), "In search of a useful theory of innovation", *Research Policy*

R. R. Nelson and S. Winter (1982), *An Evolutionary Theory of Economic Change*, Cambridge (Mass.), the Belknap Press of Harvard University Press.

F. Onida (1984), (ed.), *Technologia e Competitività internazionale dell' industria italiana*, Milano, IRS (forthcoming, Bologna, Il Mulino, 1985).

L.L. Pasinetti (1974), *Growth and Income Distribution*, Cambridge, Cambridge University Press.

L. L. Pasinetti (1977), *Lectures on the Theory of Production*, New York, Columbia University Press.

L.L. Pasinetti (1981), *Structural Change and Economic Growth*, Cambridge, Cambridge University Press.

K. Pavitt (1984), "Sectoral patterns of technical change: toward a taxonomy and a theory", *Research Policy*. ~~forthcoming.~~

K. Pavitt (1984a), *Chips and Trajectories*, Brighton, SPRU, University of Sussex, mimeo.

K. Pavitt (1984b) *International Patterns of Technological Accumulation*, Brighton, SPRU, University of Sussex, mimeo.

C. Perez (1984), "Structural Change in Industry and Kondratieff Cycles", in Freeman (1984a).

N. Rosenberg (1976), *Perspectives on Technology*, Cambridge, Cambridge University Press.

N. Rosenberg (1982), Inside the Black Box, Cambridge, Cambridge University Press.

D. Sahal (1981), Patterns of Technological Innovation, Reading (Mass.). Addison-Wesley.

F.M. Scherer (1980), Industrial Market Structure and Economic Performance, Rand McNally, 2nd. ed.

J. Schmookler (1966), Invention and Economic Growth, Cambridge (Mass), Harvard University Press.

D. Siniscalco (1983), "Il sistema produttivo: Analisi per industrie e subsistemi", Ricerche Economiche.

L. Soete (1979), "Firm size and inventive activity: The evidence re-considered", European Economic Review

L. Soete and G. Dosi (1983), Technology and Employment in the UK Electronics Industry, London, Francis Pinter.

L. Soete and R. Turner (1984), "Technological diffusion and the rate of technical change", Economic journal

P. Stoneman (1984). The Economic Analysis of Technical Change, Oxford, Oxford University Press

P. Sylos Labini (1967), Oligopoly and Technical Progress, Cambridge (Mass.), Harvard University Press, 2nd. ed.

P. Sylos Labini (1984), Le forze dello sviluppo e del declino, Bari, Laterza.

J. Tavares de Araujo (1984), Complexos Industriais e Comercio Exterior da Economia Brasileira: 1970-1983, Rio de Janeiro, Instituto de Economia Industrial, UFRJ, Discussion Paper.

J. Townsend et al. (1981), Innovation in Britain since 1945, Brighton, University of Sussex, SPRU Occasional Papers.

N.B.: The foregoing bibliography is not meant to survey the Brazilian case-studies on technological diffusion. For the latter the reader is referred to the works, among others, of J. Tavares de Araujo, F. Erber, V. Pereira, A. Guimarães, P. Tigre, R. Tauile.