department of economics
"S. Cognetti de Martiis"

Via Po, 53 – 10124 Torino (Italy)
Tel. (+39) 011 6702704 - Fax (+39) 011 6702762
URL: http//www.de.unito.it

# WORKING PAPER SERIES

## LOCALIZED PRODUCT INNOVATION.
## THE ROLE OF PROXIMITY IN THE LANCASTRIAN PRODUCT SPACE

Cristiano Antonelli

Dipartimento di Economia "S. Cognetti de Martiis"

Laboratorio di Economia dell'Innovazione "Franco Momigliano"

Working paper No. 04/2003

Università di Torino

LOCALIZED PRODUCT INNOVATION. THE ROLE OF PROXIMITY IN THE LANCASTRIAN PRODUCT SPACE[1]

CRISTIANO ANTONELLI
DIPARTIMENTO DI ECONOMIA
LABORATORIO DI ECONOMIA DELL'INNOVAZIONE FRANCO MOMIGLIANO
UNIVERSITA' DI TORINO

ABSTRACT
The introduction of technological innovations is induced by changes in product and factor markets to which firms cannot adjust by means of changes in a given technical space, because of limited information, localized knowledge and irreversibility of tangible and intangible production factors. Firms can counteract the decline in their performance and the increase in actual costs by changing their technologies, with the introduction of process and product innovations Proximity in the Lancastrian product space matters when relevant knowledge is acquired and localized by learning by doing current products, learning by using the techniques in place and learning by interacting with current customers and rivals. The rate of technological change and the mix between product and process innovations are endogenous and localized by the key role of irreversibility and by the competence accumulated by means of learning processes.

JEL CODES: O14 - O31 - O32 - O33
KEY WORDS: LOCALIZED TECHNOLOGICAL CHANGE- PRODUCT INNOVATION – PROXIMITY- BARRIERS TO ENTRY.

1 The financial support the European Union Directorate for Research is acknowledged. This work has been developed, within the context of the Key Action 'Improving the socio-economic knowledge base', as a part of the project 'Technological Knowledge and Localised Learning: What Perspectives for a European Policy?' carried on, at the Fondazione Rosselli, under the research contract No. HPSE-CT2001- 00051. Preliminary versions of this paper have been presented at seminars and workshops of the IDEFI of the University of Nice, the CRIC of the University of Manchester and the CPDA/UFRJ Program 'Institutions Organizations and Strategies' at the Institute of Economics of the Federal University of Rio de Janeiro. The comments of Ana Celia Castro, Davide Consoli, Martin Fransman, Stan Metcalfe, Pier Paolo Patrucco, Bruno van Pottelsberghe, Victor Prochnik, Michel Quèrè and Mario Calderini are acknowledged, as well as the detailed suggestions of Donald Lamberton and one referee.

## 1. INTRODUCTION

Economics of information has provided economics of innovation with substantial contributions, ever since its first steps. The effects of technological change are clear: the continual introduction of new products and new processes increases the relevance of the basic notion of information asymmetries, information impactedeness and moral hazard. The specific conditions in which information is generated and circulated and its acquisition costs become relevant also to understanding the determinants of technological change. The basic tools of economics of information and knowledge[2], such as bounded rationality, imperfect knowledge, information asymmetries, search and information costs can be applied systematically to explore the determinants of technological change and to understand the context in which endogenous technological innovations are generated and introduced by firms (Lamberton, 1971)[3]. In this context the notion of proximity in a multidimensional space plays a key role: proximity in regional space, in technical space, in product space, in technological space all matter in assessing the rate and direction of technological change.

This paper provides an extension and an application of the notion of localized technological change, traditionally applied to process innovations, to understanding the role of technological and market proximity in the introduction of product innovations. The basic ingredients of the localized technological change approach, such as the inducement

[2] The notions of information and knowledge used in the paper are consistent with the tradition of analysis that has been developed in the last 50 years in the economics of innovation. According to Stiglitz (2000) two distinct branches of economics focus their attention on the role of information and knowledge as non-conventional commodities: economics of information and economics of innovation: "The observations just made about the ways in which information and knowledge differ from conventional commodities are general: they apply both to new knowledge, about new products or processes, as well as to information, say about the characteristics of a particular investment opportunity. There have developed in the last 50 years two distinct branches of the subject -the economics of innovation and invention, focusing on what is often called knowledge, and the economics of information. Both have important implications for thinking about economic behavior "(Stiglitz, 2000: 1442-1443)

[3] Quite surprisingly Stiglitz (2002) does not emphasize his own relevant contributions (See Atkinson and Stiglitz, 1969 and Stiglitz, 1987) to the economics of innovation.

context of analysis, the key role of learning and information asymmetries and switching costs associated with bounded rationality, proximity in technical space and irreversibility apply to understanding not only the dynamics of process innovations but also the role of proximity in product space and the dynamics of product innovation.

The main contribution of this paper consists in the use of a variation of Kelvin Lancaster's (1971) concept of product space to demonstrate how the clustering of product innovations in technical and product space may be beneficial and how it affects the innovative conduct of firms. The implementation of the framework elaborated by Lancaster to analyze the choices of consumers with the analysis of the market place based upon monopolistic competition provides a context into which the role of proximity in the product space can be assessed and the dynamics of localized product innovation can be understood. In so doing the paper provides a microeconomic foundation for the analysis of induced innovations and implements it along the lines of the localized approach to analyzing technological change[4].

The paper is structured as follows. Section 2 provides a preliminary discussion about the role of proximity in product innovation both from the technological and the market viewpoint. Section 3 elaborates a simple model which makes it possible to implement the basic intuition that firms are able not only to introduce innovations when facing unexpected events, but also to choose whether to introduce product or process innovations, according to the localized context of opportunities and constraints that are defined in historic time. The conclusions summarize the results and explore some implications for empirical research, innovation policy and innovation strategy.

## 2. THE LOCALIZED TECHNOLOGICAL CHANGE APPROACH: PROXIMITY AND PRODUCT INNOVATION

In the localized approach technological change is the endogenous outcome of the creative reaction, to the mismatch between expectations and actual

[4] See McCain (1974) for a model of economic growth and induced bias in technological change that also relies upon the Lancastrian product space.

facts, of myopic firms that are not bounded to quantity-price adjustments, but are able to change also their technology in a limited technical space defined by the pervasive role of irreversibility of fixed production factors. In this tradition of analysis technological change is made possible by the continual efforts of accumulation of competence and technological knowledge based upon localized learning processes and the eventual introduction of innovations by existing agents rooted in a well defined set of scientific, technical, geographic, economic and commercial circumstances. (Atkinson and Stiglitz, 1969; David, 1975; Stiglitz, 1987; Antonelli, 1995, 1999, 2001, 2003).

Firms are viewed as biological agents, who are not limited to adjusting prices to quantities and vice versa (Penrose, 1952 and 1959; Loasby, 1999). They are also able to learn and change their technology, as well as their strategies. Technological change is primarily the result of the valorization and implementation of underlying learning processes, in doing as well as in using and in interacting, that are localized in the specific context of action of each economic agent. Technological change moreover is influenced by strategic decision making of myopic agents who nevertheless try to maximize their profits, and necessarily take into account the product and factor markets in which they are based[5].

In this approach localization in multidimensional spaces matters because of four classes of reasons: a) agents are characterized by bounded rationality and yet are able to learn. The capability and the competence acquired by means of learning processes are heavily localized in a limited technical space. Technological and organizational innovations are possible

[5] As a consequence at each point in time the market place is kept in disequilibrium between one possible equilibrium and many alternative ones introduced in a continual variety of efforts and attempts by heterogeneous and creative agents surprised by the mismatch between expectations and actual product and factor markets. The introduction of technological changes is an endless process because each innovation modifies the context anticipated by each other agent and hence induces other innovations. The process is path dependent because at each point in time irreversibility constraints the decision making of actors and yet their creative reaction can engender solutions that cannot be fully anticipated from their past. The assumptions about the irreversibility, of at least some inputs, and the key role of learning qualify the process as non-ergodic: historic time matters. The assumptions about failure induced technological change based upon reactivity, creativity and endogenous innovative capability mark the distinction between a past-dependent process and path dependent one: each innovation cannot be fully predicted from the past of the innovator (David, 1975 and 1985; Antonelli, 1999 and 2003).

only in the proximity of the specific learning context; b) proximity in regional and technological space to other learning agents makes it possible to take advantage of communication flows among complementary innovations and innovative activities and hence of contextual spillovers; c) irreversibility of fixed production factors limits the mobility in the technical space and constraints agents to make the best possible usage of existing inputs; d) relative factor prices favor the use of technologies that make the most effective usage of locally abundant inputs.

The specific contribution of this work consists in the analysis of the role of proximity in the product space. Proximity in the product space seems relevant for three classes of reasons: the role of localized learning about consumers' tastes; the effects of brand loyalty and reputation on consumers' choices; the effects of product differentiation and reputation, as sources of barriers to entry and to mobility, on market structure. Let us analyze them in turn.

*The role of proximity in the knowledge space and the generation of product innovations.*

Firms can introduce successful innovations only when sufficient competence and tacit knowledge are available. Such competence can only be acquired in localized learning processes. Because learning is a necessary condition for the efficiency of the innovation activities, the introduction of innovations cannot take place too far away from the context of action and the roots of the competence of the firm also and mainly with respect to its consumers and competitors. The competence and experience that is necessary to innovate is acquired not only in the repeated usage of a given set of capital goods and intermediary products and in the production of well identified products. Also the experience accumulated in marketing and interacting with a well defined set of consumers and competitors in a limited range of products, is necessary in order to generate new knowledge and eventually introduce new products. Interactions with actual customers are a primary source of tacit knowledge about their tastes and needs (Lundvall, 1985). No successful product innovation can be effectively and successfully introduced without some dedicated competence about the market place. The distance, in the product space, from the products being traditionally delivered to the market place, can be considered a strong factor of increasing innovation costs and decreasing efficiency in the generation of innovations. Proximity in product space matters as the prime source of information about the tastes of customers and their potential interests. Proximity in the product space matters as well as about the capabilities of competitors and their strategic attitude. The introduction of product innovations in market niches that are far away from the source of the experience of each firm is put at risk by the lack of specific competence and relevant, additional costs should be recognized (Von Hippel, 1988).

*The role of proximity in consumers choice.*

The demand for radically new products with a mix of characteristics that is completely different from the experience and competence of consumers is affected by relevant problems. As a huge literature on the diffusion of innovation shows, it takes time for new products to be fully appreciated. As Bianchi (1998) notes, the actual choices of consumers are the result of both tastes and capabilities acquired by means of experience, skills and hence localized knowledge. The demand for new products delivered by firms with low levels of reputation and brand recognition, has to take into account the burden of relevant switching costs consisting in information, search and transaction costs necessary to prospective customers to assess and value the new products (Klemperer, 1987a and 1987b). Such costs increase with the distance of the new product in term of characteristics with respect to the existing ones. Hence it is clear that the demand for new products is negatively affected by their distance in the space of product characteristics from the existing ones[6]. It seems clear that the larger is the novelty of the product, with respect to previous innovations, and the lower the reputation of the innovating firm, and the greater is the resistance of customers to accepting the new product.

*The role of proximity in the market place.*

A large literature has explored the role of barriers to entry and limit pricing in homogeneous product markets. Much less attention has been paid to

---

[6] The distinction elaborated by Philip Nelson between search goods and experience goods is relevant in this context: it is clear that proximity matters more for experience goods especially when durable products are considered (Nelson, 1970)

analyzing the effects of barriers to entry and to mobility in markets characterized by high levels of product differentiation and hence monopolistic competition (Caves and Porter, 1977). Monopolistic competition cum barriers to entry and to mobility in markets that are structured as overlapping niches with high levels of cross-price-elasticity seems a promising area of application and implementation for understanding the localized dynamics of product innovation (Sylos Labini, 1956 and 1984; Metcalfe, 1997). The price at which firms can sell in a market place characterized by monopolistic competition with barriers to entry and to mobility is affected by the idiosyncratic characteristics of their products including their reputation. Established firms which enjoy a reputation and produce specialized and differentiated goods with low levels of substitutability can secure large shares of the general demand, and they can sell their products at high price-costs margins. The levels of the price-costs margins are strictly associated with the degree of product differentiation. With high levels of product differentiation monopolistic competition cum barriers to entry and to mobility apply. Incumbents can control a captive demand and act as local monopolists. The size and the extent of their captive demand are in fact determined not only by the differences in the manufacturing costs of rival producers in adjacent product markets, but also by the effects of switching costs for consumers. (Sylos Labini 1956 and 1984; Swann, 1994; Klemperer, 1995).

A number of counter arguments about the negative role of proximity in the product space should be considered in order to provide a more balanced view. From the supply viewpoint proximity may lead to major opportunity costs. Long ago Granovetter (1973) noted that firms, which restrict their search for new techniques to a narrow range of sources, are likely to miss out on (often very important) changes originating beyond their normal networks. This point was subsequently restated and complemented by other important empirical studies by Pavitt et al. (2000)[7] using U.S. patent data to show that firms are widening their range of technological activities, presumably in part because they need to cover more fields as technologies increasingly cross industry boundaries. The point is not that proximity cannot be valuable, but that it may not always be feasible for firms to confine their learning to familiar terrain[8]. On the supply, demand and the

[7] See also Pavitt, Robson and Townsend (1989).

[8] I acknowledge the comments and suggestions of an anonymous referee.

market sides it is also clear that the actual characteristics of the economic topology matter in assessing the role of proximity. The distribution of firms and consumers in the product space is an historic factor with important effects. Following Burt (1992) it is clear that 'weak ties are essential to the flow of information that integrates otherwise disconnected social clusters into a broader society' (Burt, 1992: 26). It is clear that the introduction of a radical product innovation with a radical new mix of product characteristics can have such strong positive effects in terms of consumer's welfare as to easily undermine their resistance.

In sum, proximity is an important factor from different viewpoints in the conduct of firms when considering the introduction of a product innovation. This is quite a familiar premise in strategic management literature. Rumelt (1974) and many subsequent writers have been arguing that a firm is most likely to be profitable if it can restrict its activities to a narrow and familiar range: '…the intensive cultivation of a single field has proven, on average, financially more successful than bold moves into uncharted areas.' (Rumelt, 1974/1986: 156)[9]. Specialization in a single business and unrelated diversification appear two negative extremes both in terms of profitability and rates of growth. Related business diversification has long been regarded as the proper strategy (Porter, 1985).

Building upon the methodology introduced by Lancaster to study the actual behavior of consumers and the role of product characteristics, progress can be made with the elaboration of a framework which makes it possible to analyze the role of proximity in the product space as a determinant of the innovative conduct of firms.

---

[9] Even more explicitly Rumelt notes that « The implication is that both very little and very great diversity produce equivalent variability in earnings, but carefully controlled diversity is the best form of diversification for reducing fluctuations in earnings. We suggest that the factor responsible for this result is the ability of the diversified, but 'constrained' firm to employ the beneficial effects of negatively correlated returns by replacing products that are stagnant or declining, with close functional substitutes that are profitable and are growing for reasons related to the decline of the original products. In other words, the 'constrained' firm ties its fortunes to the satisfaction of a particular functional need (such as business-information-processing, permanent-image making, or convenience goods). It then develops a variety of products that relate to the fairly constant need and continuously searches its product line for weak points, innovating to meet changing tastes and needs » (Rumelt, 1974 /1986: 157)

## 3. A LANCASTRIAN MODEL OF LOCALIZED PRODUCT INNOVATION

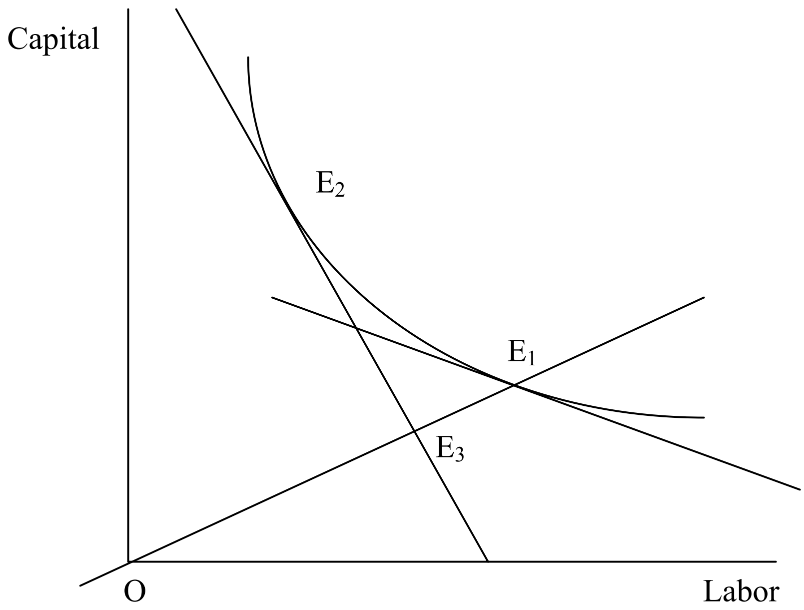
Firms can face unexpected changes in their product and factor markets either changing their technologies or their techniques. The changes in techniques imply that the firm is able to move on a given map of isoquants. Changes in product markets can be accommodated moving from one isoquant to another on given isoclines. Changes in factor markets can be accommodated by means of changes in factor intensities on given isoquants. All changes in isoclines and isoquants engender some switching costs and some costs in terms of missing opportunities for learning.

The introduction of innovations is a viable alternative when switching costs are high and technological opportunities are good. When the actual conditions of the market place do not match expectations, firms can consider adjusting passively to the new market conditions. Alternatively, they can consider the opportunity for the introduction of new technologies. A new trade-off between technical change and technological change emerges whether to change just the technique, in the existing map of isoquant or changing the technology and hence the shape of the isoquants. The trade-off will be tilted towards the introduction of technological changes when the access to knowledge is easy and conversely switching costs.

Because learning is the main source of new knowledge and learning is mainly local, technological change is localized: i.e. induced by changes in factor and product markets that cannot be accommodated by technical changes in a given map of isoquants and the related price and quantity adjustments and based upon the local opportunities for learning and generating new knowledge (Atkinson and Stiglitz, 1969; David, 1975; Antonelli, 1995).

In Diagram 1 we see that a change in relative factor price affects the viability of previous equilibrium $E_1$. The firm can either change the technique and move to $E_2$ or change the technology by means of the introduction of technological innovations, so as to find a new equilibrium in the proximity of the isocline O $E_1$, in $E_3$ or (possibly) beyond.[10] The outcome will depend upon the levels of switching costs, that is the amount of resources that are necessary to move from $E_1$ to $E_2$, compared to the amount of resources that are necessary to innovate and move towards and beyond $E_3$[11].

INSERT DIAGRAM 1 ABOUT HERE
DIAGRAM 1: THE TRADE-OFF BETWEEN TECHNICAL CHANGE AND TECHNOLOGICAL CHANGE




Much work has been done in the localized technological change approach, to inquire into the conditions, characteristics, and determinants of the trade-off between technical change and technological change. The introduction of technological changes is possible only if appropriate amounts of knowledge and competence have been accumulated and are available to firms.

The conditions of the learning processes and the determinants of the eventual production of knowledge such as the characteristics of the

[10] Actually only new solutions beyond $E_3$ can engender an actual increase in total factor productivity (See Antonelli, 1995 and 1999)
[11] See Antonelli (1995 and 1999) for a rigorous exposition.

internal organization and structure of firms, the structure of the local systems of innovations, the channels of communications among firms and between them and scientific institutions, the forms of interactions and cooperation between firms active in the same industry as well as across industries and diverse markets, the working of labor markets as vehicles for the transmission of information and knowledge, the management and the structure of the relations among users and producers, the positive and negative effects of the spillover of proprietary knowledge among rivals and more generally the governance of the appropriability conditions and the structure of intellectual property rights have received much attention. Much work has been also devoted to analyze the effects of the irreversibility and duration in historic time of capital goods and intangible assets in shaping the conduct of firms (Antonelli, 2001, 2003).

Because of the key role of learning in the production of new knowledge and the eventual introduction of technological innovation, proximity between the techniques in place and the new technology plays a key role. Learning is eminently localized: firms learn by doing and by using current techniques, they learn by interacting with current customers, actual rivals and actual suppliers, they acquire the external knowledge spilling in the close technical and regional surroundings. Technological change is localized because technological knowledge is localized, that is closely related to localized learning processes. The competence acquired in a given localized context decline with distance in regional space, for its key role in interaction among organizations and human beings, in product space for the emerging complexity associated with the variety of customers and their preferences and the variety of rivals, in technical space for the difficulty to adapt to new procedures and processes. Knowledge proximity translates into proximity in technical space, proximity in product space, proximity in regional space (Antonelli, 2001)

Along this line of enquiry an important progress can be made when the differences between product and process innovations are considered. The new –localized- technology can concern the process or the product. The trade-off between technical and technological change in fact is affected not only by the opportunity for the introduction of process innovations, but also by the prospects for the introduction of product innovations. Firms, in other words, consider two joint choices: the first is whether to introduce technical or technological change and the second, whether to introduce product or process innovations.

Process innovations make it possible to increase efficiency and face adverse market conditions with a reduction in production costs. Product innovations make it possible to increase the quantities that can be successfully delivered to the market place. In turn the introduction of product innovations requires not only the command of technological knowledge, but also the competence and experience acquired by means of learning by doing and by interacting with the customers.

Competition in Schumpeterian markets, where emphasis is on innovation and rivalry, is based upon product differentiation and product innovation rather than price. In this context monopolistic competition cum barriers to entry and to mobility proves to be the appropriate analytical framework. Each firm is a local monopolist in a niche product market. The demand for the family of substitutable products is split into a variety of niches. The size of each product niche, that is of the captive demand for each local producer, depends upon the costs and related market prices for potential entrants for their own products, narrowly defined in terms of product characteristics. Incumbents charge monopolistic prices upon their own captive demand. The dynamic distribution of firms in the product space and the costs of mobility and the opportunities for rival entry become key issues (Scherer, 1984 and 1992; Swann, 1994)[12].

The framework elaborated by Lancaster (1971) to study the choices of the consumers faced with a variety of products that are differentiated with respect to a variety of characteristics is very helpful in our context. The notion of product space provides a unique context in which the analysis of the role of product innovation can be carried out. Moreover it can be easily used and implemented with a simple analytical and geometric exposition (Gravelle and Rees, 1981).

---

[12] Much theoretical work on product differentiation and the effects and causes of product and brand variety has been based upon a model of spatial rivalry derived from the well-known Hotelling model of spatial duopoly. Little attention has been paid in this context to the analysis of technological change and the choice between product and process innovation (Martin, 1993).

Let us start with the formal introduction of the characteristics of the goods, as distinct from the goods themselves:

(1) $A = ( a_1, \ldots..a_n)$ denote a bundle of characteristics.

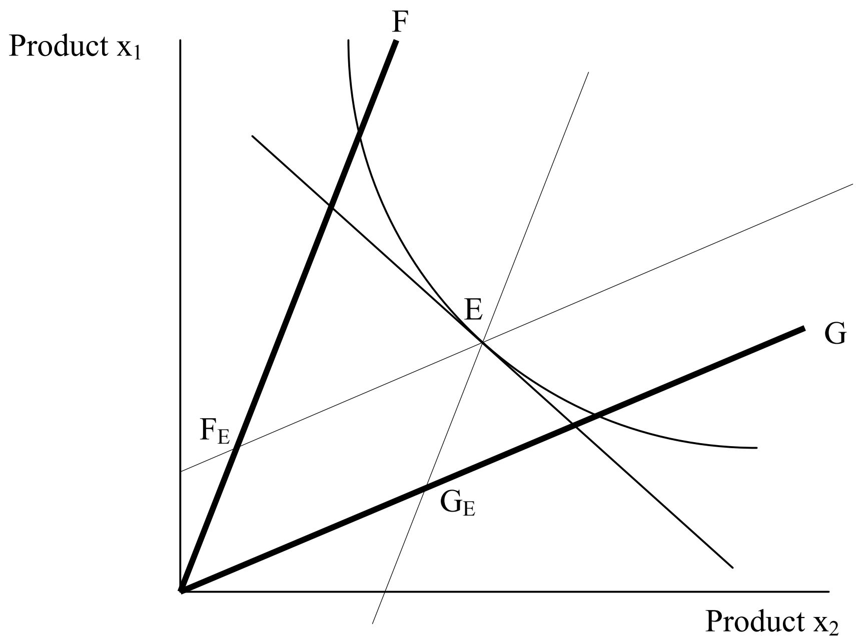
The amount of each characteristic depends on the bundle of goods:

(2) $a_i = f ( x_1\ldots..x_n) = f^i (x)$

The goal of the consumer is to optimize her utility, as it is generated by the mix of goods that can be acquired and hence by the mix of characteristics that each good contributes, for given prices of the goods and a budget (B).

INSERT DIAGRAM 2 ABOUT HERE

DIAGRAM 2: EQUILIBRIUM IN A LANCASTRIAN PRODUCT SPACE




Geometrically, each good is represented by a ray and the prices for the good are defined in terms of the distance on the ray from the origin (See rays F and G in Diagram 2 where the vertical axis represents the characteristic $x_1$ and the horizontal one the characteristic $x_2$). The budget line is easily identified as the linear combination of all the quantities of the different goods that can be purchased with a given budget B. The standard maximization easily applies:

$$(3)\ \max u\,(a_1, \ldots\ldots a_n) \quad \text{s.t.}\ (i)\ \Sigma\, p_j\, x_j = B \quad (ii)\ a_j' = f^j\ x_1\ldots\ldots x_n)$$

It should be clear that the total amount of characteristics produced by the bundle of goods acquired is the result of the sum of the specific characteristics generated by the accessible quantity of each good. The well known ‘parallelogram rule’ makes sure that a linear combination of goods can always be identified so that the desired and optimum levels of characteristics chosen by the consumers can be ‘generated’ by the appropriate mix of goods.

In Diagram 2 the equilibrium quantities $F_E$ and $G_E$ are identified by means of the parallelogram rule as the projection of the equilibrium point E.

Building upon the analytical context provided by the merging of the analysis of monopolistic competition cum barriers to entry and mobility, we assume that each firm is a local monopolist in that she is the single supplier of each good: each firm produces the good defined by the slope of each ray. Hence each ray represents both a good and a firm. The size of the demand for each product depends upon the utility function and the budget of the consumer and upon the extent to which the product can be substituted by a differentiated and yet rival product. The notion of cross price elasticity applies here.

Let us assume that the equilibrium situation identified with a given set of preferences of consumers, given cost conditions for a given family of rival producers, and a distribution of single incumbents in a given set of product niches, is satisfactory for all. Changes to such an equilibrium condition can be brought by: i) the reduction of the prices of the goods sold by the competitors, ii) the increase in the market price for the firm, due to any increase in input costs, and iii) a change in the preferences of the consumers who now like better other products and other characteristics.

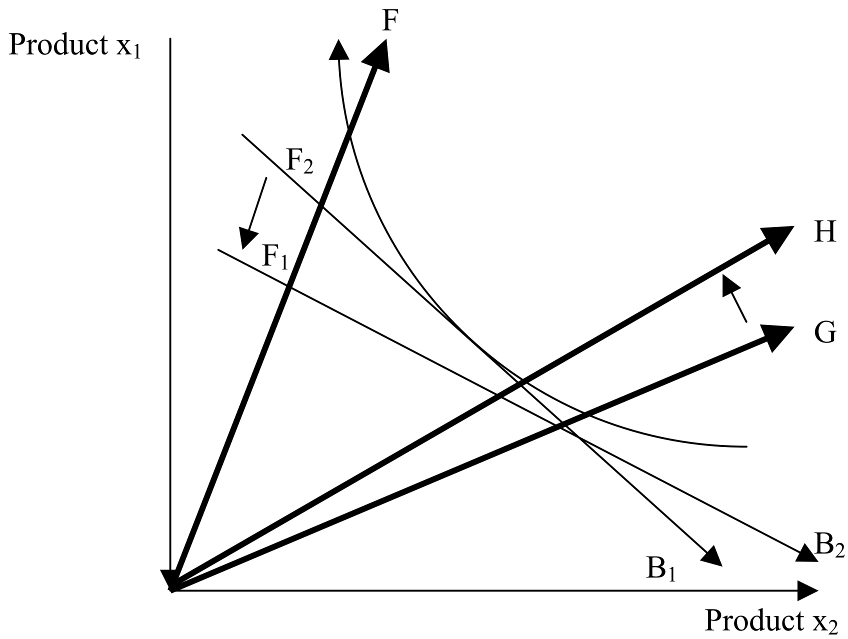
These changes lead to a reduction in the quantities delivered in the market place by at least one of the firms previously in equilibrium and hence in a reduction of her profits. The reduction can be so sharp that actual losses emerge.

The firm is now exposed to a clear decline in the levels of performances and of satisfaction. A reaction is necessary: it can be a passive one and consist in the traditional technical change defined as a movement in the space of existing isoquants or a more creative one so as to include a change in the routines and the eventual introduction of innovations either in the product or in the process. The difference between current profits, after the changes in the market place, and the profits that should have been possible without such changes is indicative of the amount of resource the firm is ready to commit in order to bring about the changes that are likely to restore the expected levels of profitability.

In other words, because of the mismatch between expectations and the actual conditions in the markets place, the firm cannot rest in the position that had been planned. The introduction of technological innovations is a viable alternative to technical change. Both adjustments are possible but are costly. Technical change in fact, because of irreversibility of existing production factors and limited knowledge about the existing techniques, requires some switching activity. Technological change on the other hand, by definition, is not on the shelf and its introduction in turn requires some innovation activities. Technological change can consist of either process innovation or product innovations. A combination of product and process innovations can also be considered. Process innovations can be easily measured in terms of increased efficiency in the production process. Product innovations can be measured in terms of the change in the slope of the ray representing the new product in the Lancastrian space of product characteristics.

INSERT DIAGRAM 3 ABOUT HERE

DIAGRAM 3: PRODUCT AND PROCESS INNOVATION IN A LANCASTRIAN PRODUCT SPACE




Specifically here the metrics of the innovation output are measured respectively:

i) for process innovations, by the reduction in the price, i.e. cost plus markup, the firm can achieve in the market place and hence in the distance from the origin along the ray (See in Diagram 3 the new intersection $F_2$ between the new budget line $B_2$ and the ray F );

ii) for product innovations, by the changes in the slope of the ray defined in terms of product characteristics, with respect to the original one (See in Diagram 3 the change in slope between the old ray G and the new ray H).

The choice set is now framed. The firm faces two nested frontiers of possible changes in order to solve the mismatch between plans and real markets conditions. The first frontier of possible changes is the frontier of possible adjustments, which makes it possible to compare the results of resources invested in either technical changes or technological ones. The second frontier, the frontier of possible innovations, compares the kinds of technological change, whether it consists of product or process innovations. The frontier of possible innovations has a concave and asymmetric shape that reflects the strong effects of distance, in the space of product characteristics, on the introduction of product innovations. This effect is stronger in the introduction of product innovations rather than in process innovations (See Diagram 4).

The position of the frontier of possible adjustments is defined by the amount of resources R that the firm should invest just to switch from the previous equilibrium technique to the new one. The search for the correct solution in other words is identified as a maximization process where the firm tries and maximize the amount of changes, including technological innovations, that can be generated with a given amount of resources set by the levels of switching costs[13].

The firm can identify the correct solution, in the given context of action in the market place, with the existing technological opportunities and learning conditions, by means of standard maximization of the output, for two given nested frontiers, when two nested isorevenues are defined. The first isorevenue is defined by the absolute levels of the revenue generated by all adjustment activities consisting in the revenue made possible by the introduction of new techniques and the revenue made possible by the introduction of the new technologies respectively. The second isorevenue measures the bundle of revenues generated by either product or process innovations.

Formally we see the following relations:

(4) $TC = a(R)$

(5) $SW = b(R)$

---

[13] The firm can 'discover' to her surprise that the equilibrium amount of possible adjustments makes it possible to introduce a total factor productivity increasing technological change which leads the firm beyond equilibrium point $E_3$ (See Diagram 1). This is clearly a case for procedural rationality as opposed to substantive rationality (Simon, 1982).

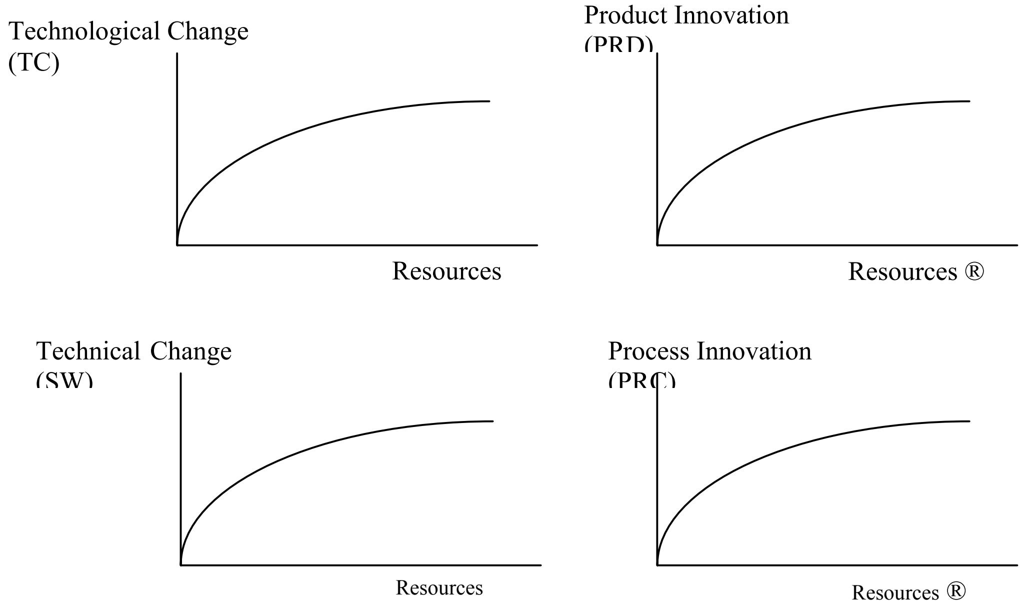
(6) PRD = c (R)

(7) PRC = d (R)

where TC measures the amount of technological innovation, necessary to change the technical space that the firm, can generate taking into account the internal competence and knowledge accumulated and the external knowledge she can access; SW measures the amount of technical change necessary to move in the existing technical space and reflects the levels of irreversibility and rigidity of tangible and intangible capital; PRD measures the amount of product innovation and PRC measures the amount of process innovation that can be generated with a given amount of dedicated resources (R) defined by the amount of switching activities the firm needs to complete to move from one equilibrium point to the other.

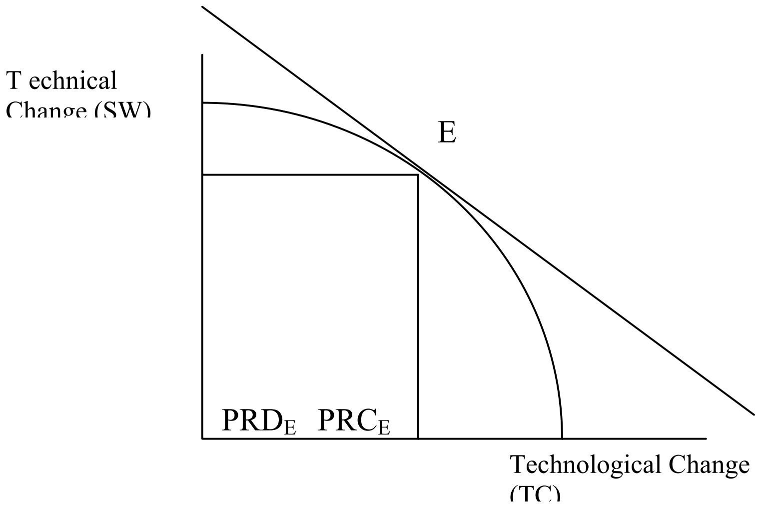
INSERT DIAGRAMS 4a AND 4b ABOUT HERE

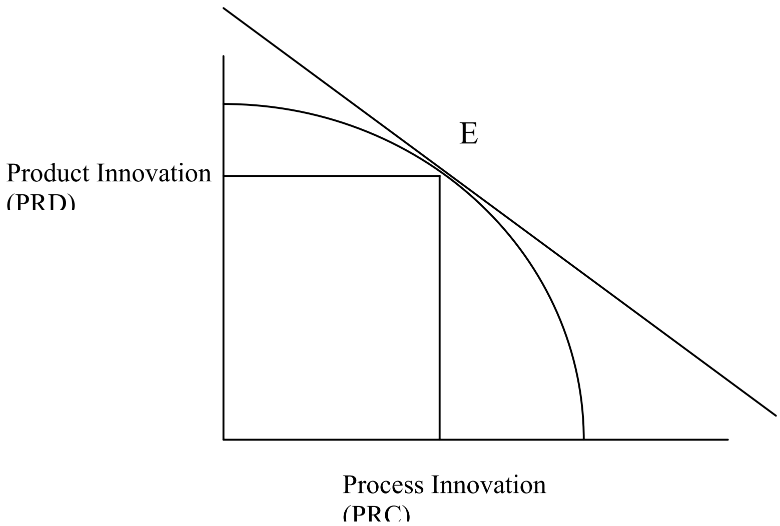
DIAGRAM 4a: THE PRODUCTION OF TECHNOLOGICAL CHANGE (TC), PRODUCT INNOVATION (PRD), PROCESS INNOVATION (PRC) AND TECHNICAL CHANGE (SW) WITH A GIVEN AMOUNT OF RESOURCES (R).



It is clear that the relationship between the four production activities is essential to define the outcome of the search process initiated by the changes in the product markets. It seems clear that the larger is the efficiency in the production of technological changes and the lower the efficiency of switching, and the larger the amount of innovations introduced. Correspondingly, the larger is the efficiency of product innovation and the smaller the efficiency of the generation of process innovations and the larger will be the amount of new products each firm will generate.

DIAGRAM 4b: THE NESTED FRONTIERS OF POSSIBLE ADJUSTMENTS AND POSSIBLE INNOVATIONS



To make this point more compact, let us now assume that a frontier of possible adjustments can be considered, such that for a given amount of resources (R) necessary to face the mismatch, firms can generate an amount of either technological change (TC) or technical one (SW). Nested to the frontier of possible adjustments we find a frontier of possible innovations that can be obtained with the introduction of either product innovations (PRD) or process innovations (PRC). Specifically the shape and the slope of the innovation frontier reflects the negative effects of the distance in terms of the technological opportunities associated and based upon the localized competence built by means of localized learning by doing and by interacting in the market place with actual customers. Formally this amounts to saying that:

(8) $SW = e(TC)$

(9) $PRD = f(PRC)$

In order for standard optimization procedures to be operationalized, two isorevenue functions need to be set. The first defined as the revenue of adjustments (RA) compares the revenue that adjustments by switching in the technical space (SW) yield with respect to the revenue of innovation (RI). The second isorevenue includes the revenue generated by the introduction of product innovations (PRD) and the revenues generated by the introduction of process innovations (PRC). Formally we see:

(10) $RA = s\,SW + t\,RI$

(11) $RI = r\,PRD + z\,PRC$

where s and t measure the unit revenue of switching and the unit revenue of technological change; r and z measure respectively the unit revenue of the amount of product and process innovations generated with the given amount of resources available for innovation and induced by the new and unexpected conditions of the product and factors markets.

The system of equations can be solved with the standard tangency solutions so as to define both the mixes of product and process innovations, which in each specific context firms are advised to select and the amount of technological change with respect to switching the context suggests selecting. The system of equilibrium conditions is in fact:

$$e'(TC) = t/s$$

(12)

$$f'(PRC) = z/r$$

subject to $TC = PRD + PRC$ and $R = R_F$[14]

The cases of either only technical change or only technological change and in turn either product or process innovations are extreme solutions. Much of the real world can be found in between such extremes. Firms are induced to innovate by the mismatch between actual and expected conditions of their production set and their market conditions, necessarily built upon irreversible decisions taken on the basis of myopic expectations which are not met by the disequilibrium conditions in product and factor markets. The type of technological change is influenced by the relative profitability of introduction of product innovations with respect to process ones.

The slope of the innovation isorevenue reflects the effects of distance in the product space on the levels of price cost margins and equilibrium demand for product and process innovations respectively. According to the shape of the innovation isorevenue, both the composition of technological change, whether it consists mainly of product or process innovations, and the mix of possible changes, whether they consist mainly of switching activities or technological changes, are affected. There are three possibilities.

First, the isorevenue has a single slope: prices do not change with distance. In this case there are no negative effects of the distance in the product space on the demand for the new product and on the prices because of increased competition. Hence the introduction of product innovations will be favored.

[14] $R_F$ is set by the amount of resources the myopic firm, unable to anticipate the 'technological surprise', should in any case invest in order to switch.

Second, the isorevenue is convex: the larger is the distance of the new product from the original one, as measured by the slope of its ray in the product characteristics, and the larger are both prices and equilibrium demand. The number of rivals in the product space of rivals is low and the size of customer's niches interested by the new product is very high. The introduction of product innovations is much favored. As a consequence also the equilibrium amount of technological change, with respect to switching, is increased.

Finally, the isorevenue is concave. This would reflect the case in which the larger is the distance of the new ray from the original one and the lower are the prices the innovating firm can charge and the smaller the quantities of the new product the firm can actually sell. Specifically, we see here that the larger is the distance of the product innovation ray from the origin and: i) the lower are the positive effects on prices of reputation and brand loyalty and ii) the lower are the barriers to entry and to mobility for rivals producing products with characteristics that are closer and closer and the lower the protection for incumbents provided by reputation and brand loyalty. The reduction in this distance engenders an increase in the substitutability for consumers and an increase in their switching costs. Clearly in this case the firm would prefer to introduce process innovations and possibly rely more on switching activities rather than on technological change in order to deal with the mismatch between plans and facts.

The equilibrium conditions identified by equation (12) capture the essence of the dynamics[15]. The role of proximity in both technical and product space can now be fully appreciated. Firms tend to introduce product innovations in a limited region of the product characteristics space, as they are constrained by the negative effects of distance on both their actual

[15] Stochastic factors play a major role here. Technological change should be viewed as the lucky outcome of a fragile set of highly qualified conditions. Successful - total factor productivity enhancing - innovations are based upon the localized competence and experience of agents induced to innovate by the mismatch between expectations and real market conditions and irreversibility, but are really possible only when a large number of complementary conditions apply. Among such conducive conditions co-localization within technological districts, effective communication flows with other firms, active in upstream and downstream industries, as well as in the industry, creative interactions with universities research centers, complementarity with other innovation processes, access to financial resources, play a key role. When such conditions are lacking, the reaction of firms is limited to sheer technical change i.e. traditional substitution along existing isoquants.

competence and technological capability in the innovation process and on their demand and on the conditions of the monopolistic rivalry. New products can be introduced in a broader region of the Lancastrian space of characteristics when the density of firms is lower and the distance from the original specification of the product sold by each innovator makes it possible to deliver products that are much more appreciated by consumers (and when little competition is found).

The Lancastrian approach to model the choice set of consumers provides a fertile and putty methodology which helps in framing not only the static context of analysis of the role of characteristics of products in the choice of consumers, but also a dynamic context, one where the characteristics of the products can change. In so doing, the Lancastrian methodology becomes an important device to understand and model the dynamics of localized product innovations.

## 4. CONCLUSION

Much empirical and theoretical work has made it possible to appreciate the strong localized character of technological change and the role of path dependence in the determination of its rate and direction.

Such analysis has paid much attention to the factors that localize technological change in the technical space, because of the role of irreversibility of the existing stock of fixed capital and the effects of learning in the accumulation of the competence and technological knowledge that are necessary for the successful introduction of new technologies. Many analyses have studied the role of proximity in geographic and knowledge space as factors localizing technological change because of the key role of complementarity and externalities in the generation of new knowledge and the key role of communication in standing over giants' shoulders. Communication and hence spillovers are easier among agents who are close to each other both in the actual geographic space and in the knowledge space. It is easier for firms to introduce technological innovations that complement each other and take advantage of strong elements of commonality. Complementarity and interdependence among technological innovations and hence technological proximity, in the form of both technological fungeability and technological complexity, add on so as to build technological systems and favor the localization of further innovative efforts and additional technological innovations within such systems.

Little analysis had been, so far, devoted to understanding the dynamics of localized technological change in the introduction of product innovations. The empirical evidence available[16] however suggests that product innovations introduced by each firm tend to be localized in a limited region of the space of product characteristics. Longitudinal analyses of firms able to survive in the long run confirm that they tend to specialize in a narrow range of products.

The introduction of the now traditional set of hypotheses about the role of proximity and distance not only in learning but also in the competitive space characterized by monopolistic competition yields important results that confirm the dynamics of localized technological change also with respect to the introduction of product innovation. The analytical framework introduced by Lancaster (1971) proves to be especially fertile and productive, able to accommodate the analysis of the innovation process in the space of product characteristics. Moreover it seems that the Lancastrian approach used so far as a tool to stretch the localized technological change approach provides a useful analytical context into which much evidence provided by strategic management finds an appropriate economic understanding.

It seems clear that product innovation is more localized the more specific and localized is the process of accumulation of competence and the more relevant is the latter in the generation of technological knowledge and the more dispersed the distribution of firms in the product space. Such results can become useful from the viewpoint of both the economics of industrial strategy and from an innovation policy perspective.

The argument developed so far leads to articulation of a number of clear and testable hypotheses. First, the levels of R&D activities should be

---

[16] See Lang and Stultz (1994) for a clear result and Besanko, Dranove and Shanley (2000) for a general survey on these findings.

positively associated to the variety of product innovations, as distinct from the quantity of product innovations, introduced by firms. [17]

Second, constrained diversification is most successful when learning by doing, by using and by interacting with customers are relevant factors that cannot be dispensed with..

Thirdly, the lower are the technological opportunities for the introduction of process innovations, for given levels of inducement pressure, and the larger is the variety of product innovations. The heterogeneity of product innovations and hence the diversification and differentiation of firms should be larger in traditional industries, rather than in high-tech ones. In these industries the introduction of process innovations depends mainly upon technological change introduced upstream and embodied in capital goods and intermediary products.

Fourth, joint ventures and mergers and acquisitions are complementary strategic steps for firms willing to extend the ray of their product innovations. The acquisitions of firms already active in other product markets increases in fact the command of the technological knowledge and the competence on the new niches that are far away from the original core of the firm.

The introduction of general-purpose technologies, such as in the case of the gale of new information and communication technologies, can have an important impact on the picture elaborated so far. High levels of fungeability in fact characterize the new generic knowledge, which make it possible to favor the introduction of an array of new product innovations even in fields that are far away from the traditional localization of firms. A related hypothesis, hence, can be elaborated and eventually tested: the higher is the penetration of new information and communication technologies, both at the firm and the system level, the greater is the variety of product innovations being introduced both by each firm and by each economic system.

[17] The statistics available on R&D activities capture in fact quite well the actual amount of codified knowledge firms can command.

Finally, it seems clear that the choice between process and product innovations is affected by the role of historic time and creativity, and specifically by the balance between internal and external irreversibility and learning conditions. Demand and competitive effects are external to each firm and reflect the given characteristics of the existing distribution of firms in the product space, a well as of the tastes and density of consumers. The effects of competence and switching costs instead are internal to each firm and reflect respectively the role of localized technological knowledge and its strong association to localized learning processes, and the effects of historic time in the accumulation of tangible and intangible production factors.

Here again the role of path dependence can be appreciated. The localization of firms in the space of product characteristics at time t has in fact major consequences on their innovative behavior and hence on their location in the space characteristics at time t+1. At the same time the process is not past dependent because the mix of competence and technological knowledge available at each point in time can lead the firm in any possible direction.

Specific conditions affecting learning processes, such as the localization in regions where innovation activities cluster and scientific and technological communication among complementary research activities is easier, can favor the introduction of radical product innovations that push the firm far away from the original localization in the product space, but closer to the core competence of the region.

The availability of external sources of codified knowledge with a strong scientific content can help firms to venture into new product characteristics far away from traditional ones, so as to complement and compensate for the dwindling support of tacit knowledge built upon learning that is declining with the distance from the traditional set of operation. An effective science and technology policy is a strong enabling factor, which strengthens the inducement mechanisms and helps firms to rely upon innovations when facing adverse market conditions.

BIBLIOGRAPHY

Antonelli, C. (1995), *The economics of localized technological change and industrial dynamics,* Kluwer, Boston.

Antonelli, C. (1999), *The microdynamics of technological change*, Routledge, London.

Antonelli, C. (2001), *The microeconomics of technological systems,* Oxford University Press, Oxford.

Antonelli, C. (2003*), The economics of innovation, new technologies and structural change,* Routledge, London.

Atkinson, A.B. and Stiglitz, J.E. (1969), A new view of technological change, *Economic Journal* 79, 573-578.

Besanko, D., Dranove, D. and Shanley, M (2000), *Economics of strategy*, John Wiley & Sons, New York.

Bianchi, M. (ed.) (1998), *The active consumer*, Routledge London.

Burt, R.S. (1992), *Structural holes. The social structure of competition*, Harvard University Press, Cambridge, Mass.

Caves, R.E. and Porter, M.E. (1977), From entry barriers to mobility barriers: Conjectural decision and contrived deterrence to new competition, *Quarterly Journal of Economics* 91, 241-261.

David, P.A. (1975), *Technical choice innovation and economic growth*, Cambridge University Press , Cambridge.

David, P.A. David, (1985), Clio and the Economics of QWERTY, *American Economic Review* 75, 332-37.

Gravelle, H. and Rees, R. (1981), *Microeconomics*, Longman, London and New York.

Granovetter, M.S. (1973), The strength of weak ties, *American Journal of Sociology* 78, 1360-1380.

Granovetter, M.S. (1983), The strength of weak ties: A network theory revisited, in Collins, R. (ed.), *Sociological theory*, Jossey-Bass, San Francisco, (pp. 201-233).

Klemperer, P. (1987a), Markets with consumer switching costs, *Quarterly Journal of Economics* 102, 375-394.

Klemperer, P. (1987b), The competitiveness of markets with switching costs, *Rand Journal of Economics* 18, 138-150.

Klemperer, P. (1995), Competition when consumers have switching costs: an overview with an application to industrial organization, macroeconomics and international trade, *Review of Economic Studies* 62, 515-539.

Lamberton, D. (ed.) (1971), *Economics of information and knowledge*, Penguin, Harmodsworth.

Lancaster, K. (1971), *Consumer demand: A new approach*, , Columbia University Press, New York.

Lang, L. and Stultz, R. (1994), Tobin's *q*, corporate diversification, and firm performance, *Journal of Political Economy* 102, 1248-1280.

Loasby, B.J. (1999), *Knowledge institutions and evolution in economics,* Routledge for Graz Schumpeter Lectures, London.

Lundvall, B.A. (1985), *Product innovation and user-producer interaction*, Aalborg University Press, Aalborg.

Martin, S. (1993), *Advanced industrial economics*, Basil Blackwell, Oxford.

McCain, R.A. (1974), Induced bias in technical innovation including product innovation in a model of economic growth, *Economic Journal* 84, 959-966.

Metcalfe, J. S. (1997), *Evolutionary economics and creative destruction*, Routledge, London.

Nelson, P. (1970), Information and consumer behaviour, *Journal of Political Economy* 78, 311-329.

Pavitt, K. (2000), *Technology, management and systems of innovation*, Edward Elgar, Cheltenham.

Pavitt, K., Robson, M., Townsend, J. (1989), Technological accumulation, diversification and organization in UK companies, 1945-83, *Management Science* 35, 81-99.

Penrose, E.T. (1952), Biological analogies in the theory of the firm, *American Economic Review* 42, 804-819.

Penrose, E.T. (1959), *The theory of the growth of the firm*, 1st and 3rd editions, Basil Blackwell (1959) and Oxford University Press (1995), Oxford.

Porter, M.E. (1985), *Competitive advantage*, The Free Press, New York.

Rumelt, R.P. (1974), *Strategy, structure and economic performance*, Harvard Business School Classics (2nd edition, 1986), Boston.

Scherer, F. M. (1984), *Innovation and growth: Schumpeterian perspectives,* MIT Press, Cambridge.

Scherer, F.M. (1992), *International high-technology competition*, Harvard University Press, Cambridge.

Simon, H.A. (1982), *Metaphors of bounded rationality. Behavioral economics and business organization*, MIT Press, Cambridge.

Stiglitz, J.E. (1987), Learning to learn, localized learning and technological progress, in Dasgupta, P. and Stoneman, P. (eds*.), Economic policy and technological performance*, Cambridge University Press, Cambridge, (pp. 125-153).

Stiglitz, J.E. (2000), The contributions of the economics of information to twentieth century economics, *Quarterly Journal of Economics* 114, 1441-1478.

Stiglitz, J.E. (2002), Information and the change in the paradigm in economics*, American Economic Review* 92, 460-502.

Sylos Labini, P. (1956), *Oligopolio e progresso tecnico*, Milano, Giuffrè. Translated in English (1962), *Oligopoly and technical progress*, Harvard University Press, Cambridge.

Sylos Labini, P. (1984), *The forces of economic growth and decline*, MIT Press, Cambridge.

Swann, P. (ed.) (1994*), New technologies and the firm: Innovation and competition*, Routledge, London.

Von Hippel, E. (1988), *The sources of innovation*, Oxford University Press, Oxford.