WSG Diskussionspapiere

WSG 10/91

# Technological Change and Innovation Behaviour in Industry:

## A Conceptual and Methodological Framework

Manfred M. Fischer

Institut für Wirtschafts- und Sozialgeographie

Wirtschaftsuniversität Wien

Department of Economic and Social Geography

Vienna University of Economics and Business Administration

WSG Discussion Papers

**Institut für Wirtschafts- und Sozialgeographie**
**Wirtschaftsuniversität Wien**

**Vorstand: o.Univ.Prof. Dr. Manfred M. Fischer**
**A - 1090 Wien, Augasse 2-6, Tel. (0222) 313 36 - 4808**

**WSG 10/91**

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**WSG-Discussion Paper 10**

**March 1991**

ISBN 3 85037 010 0

## 1. Introduction

During the last two decades a substantial body of knowledge has been developed in the study of technological change, and much of it is being used by policy makers in the public and private spheres. While it is true to say that we now understand a great deal more about technological change processes at the micro- and the macro-level, it nevertheless remains true that there is currently no satisfactory general theory of technological innovation. Despite the progress which has been made, the gaps in knowledge are still great. The economics of technological change though rapidly growing is still at the stage where many basic facts and theories or conceptual models are missing.

Evidently a fuller understanding of the conditions under which technological advance takes place is warranted. Technological change refers to all the changes in technology and techniques which lead to new products, new processes and new methods in industrial and distributional organisation and covers all the activities related to the innovation process, but also those related to the transfer and diffusion of knowledge. Research on technological change deals explicitly or at least implicitly with the questions why innovations occur, where innovation does take place and how innovations diffuse in time and space. Detailed knowledge on these questions is still rather fragmentary.

The emphasis in this paper is on conceptual and empirical contributions to the innovation process in general and innovation behaviour and performance in particular. In this paper an attempt will be made to mediate elements from different theoretical contributions and conclusions from empirical research into a conceptual and statistical model framework for analysing determinants to innovation behaviour and performance.

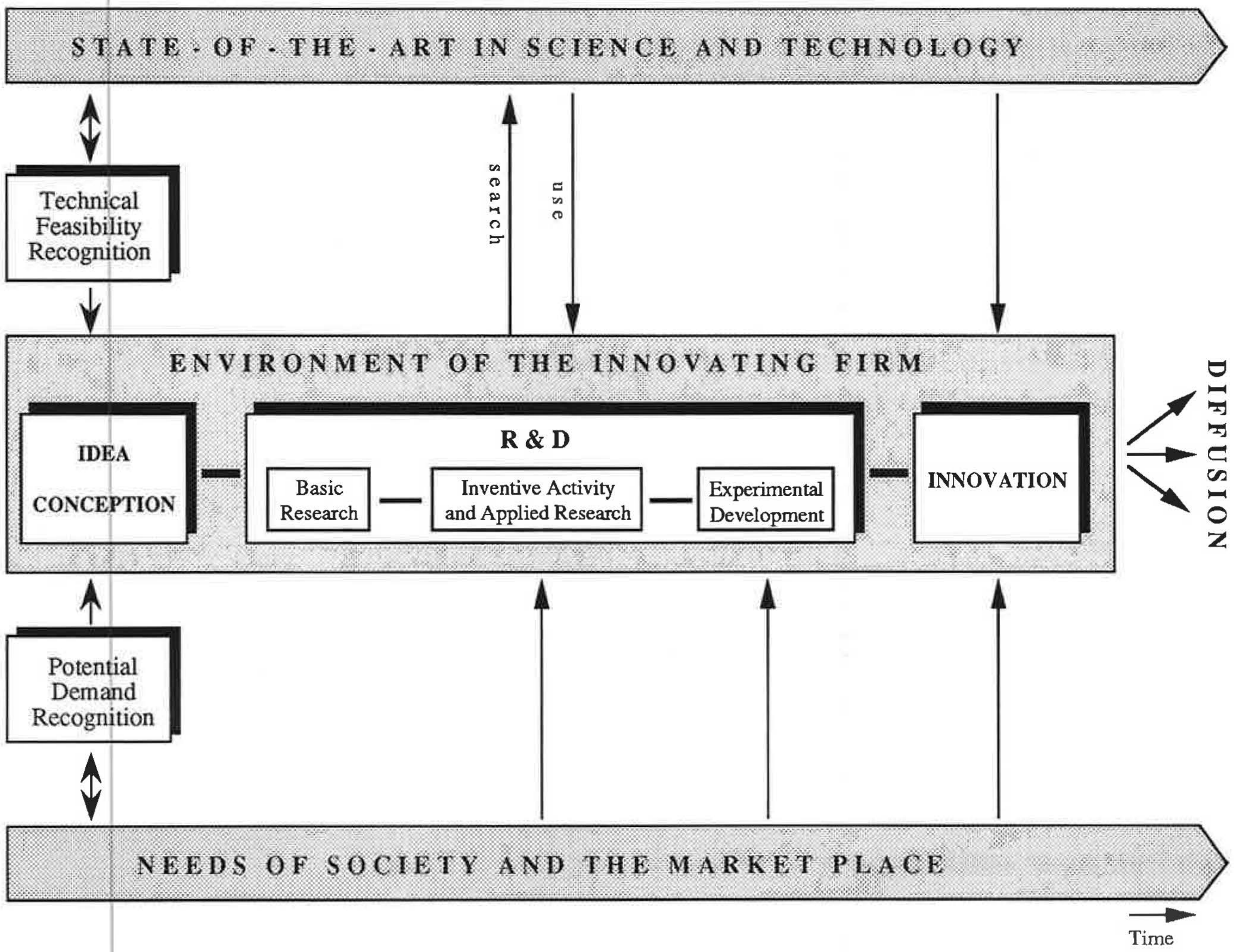
The paper starts with a brief characterisation of a conceptual model of the technological innovation process which combines the open system view of an innovating firm with the notions of technology-push and perceived market needs, considers Research and Development (R&D) in some more detail and suggests to rely on a system of input-, throughput- and output indicators to measure the complex and multidimensional nature of the process rather than on a single indicator such as patent statistics or R&D figures. Any explanation and prediction of technological change has to be based on a deeper understanding of the major driving forces of such changes. In section 3 four major categories of determinants will be discussed in some detail which influence innovation behaviour and performance at the micro level; namely factors related to the firm´s activities, locational influences, factors related to the firm´s interaction with its wider sectoral, technical and economic environment, and factors which relate to the political-institutional context in which the economic process has to take place. Little is known how the individual determinants interact with each other and influence innovation activities, measured in terms of product and process innovatons. To deal with this issue a statistical model approach will be suggested and its flexibility illustrated using an example of a wider research project on innovation activities in Austrian manufacturing industry. The paper proceeds with a discussion of some conclusions.

## 2. A Conceptual Model of the Technological Innovation Process

Technological innovation is a complex techno-socio-economic process which involves extremly intricate interactions, both intra-firm and between the firm and its economic and technological environment. For a long time models of the innovation process emphasized the causal role of scientific and technological advances and their transformation into commercially valuable systems or components that perform specialised tasks. In general, the models were linear in nature, with distinct steps and stages of development such as fundamental research and preliminary development, focused development and marketing. The linearity does not mean that research is not carried out in the later stages of the process, only that the nature of that later research is much more focused and directed. From the late 1960s onwards, largely as outcome of several empirical studies on actual innovations, the role of demand-pull, or at least forward linkages to the market place, started to be emphasized increasingly as a crucial factor in innovation. This emphasis resulted in linear need-pull models of the innovation process (see Rothwell 1983).

During the past decade, both pure technology-push and need-pull models of the innovation process have been criticised as extreme and atypical examples of a more general process of coupling science, technology and the market place. On the one hand it became increasingly clear that more R&D not necessarily leads to more innovation, on the other hand, overemphasis on

**Figure 1: An Interactive Model of the Innovation Process**



market needs may result in a regime of technological incrementalism and a paucity of more radical innovations (Rothwell 1983). The examples of Route 128 in Boston and Silicon Valley are reminding that a strong knowledge basis is an important factor on the emergence of high tech complexes.

The new insights into the innovation process are elaborated in Figure 1 combining the open system view of an innovating firm with the notions of technology-push and perceived market needs. According to this view the firm interacts more or less strongly with its locational environment as well as with the wider techno-economic and sectoral environment.

The innovation process itself covers a succession of operations, i.e. the transition from the idea to the materialisation in form of new products and/or production processes, and is regarded as a logically sequential, though not necessarily continuous or linear process which can be disaggregated into three functionally separate, but of course interacting stages:

* **first**, the stage of recognition and idea conception,

* **second**, the stage of Research and Development (R&D), and

* **third**, innovation, i.e. the commercial introduction of a new product, the utilization of new process or a new organisational technique as outcome of the innovation process.

The distinction between an innovation and an adoption is difficult and frequently inappropriate. Adoption usually requires adaption and even further innovation. Thus, here no distinctions will be made between the innovation and adoption process.

Figure 1 represents the confluence of technological capabilities on the one hand and perceived market needs on the other within the framework of the innovating firm. Interactions and feedbacks are inherent characteristics of the innovation process itself. The various R&D-functions are not only linked with the other functions (marketing, production, engineering) inside a business company, but are also related to external developments in the technological, sectoral, economic and commercial environments.

Of course, activities carried out in all the innovation stages are influenced by the locational and the wider environment in which the innovation organisation operates. Such external conditions include inter alia, the political-institutional framework, legislation, environmental and economic regulations, political climate, cultural aspects, etc. and the whole range of public measures designed to facilitate the technological transformation process within the firm (see Rothwell 1983). Innovation-relevant ideas may result from science and technology developments (technology push), the market (demand pull) or from a linking of both, i.e. an increasing recognition and clarification of technological possibilities and assessments of relevant market needs. Technically progressive firms obtain knowledge from customers and suppliers, from external knowledge sources in the public and private sectors as well as generate it internally.

Research and Design activity is a fundamental component of the innovation process. It aims at expanding and applying the stock of knowledge to commercial needs and encompasses work of different kinds. The distinction between categories of work is often hazy. But to generalize, it seems to be useful to distinguish three broad types of activities (see Figure 1):

* **Basic research**,
* **Applied research**, and
* **Experimental development.**

These three major categories of R&D may be associated with specific task environments. The most distinguishable attributes of these environments are the relative presence of commercial objectives, the operational time horizon, the degree of uncertainty associated with the particular R&D activity and barriers to entry (Howells 1984).

Basic research has strong ties to pure science and refers to original investigations for the advancement of scientific knowledge without any particular commercial application in view. Of course, basic research is a long-term very costly and risky exercise with unpredictable commercial benefits. Thus, it is not surprising that due to cost considerations, the high element of risk involved and the long-term nature and pay off of the research, basic research is primarily undertaken in research units of higher education and in governmental research establishments rather than the industrial firm, even if greater efforts in fundamental research may be observed in industrial R&D-laboratories very recently.

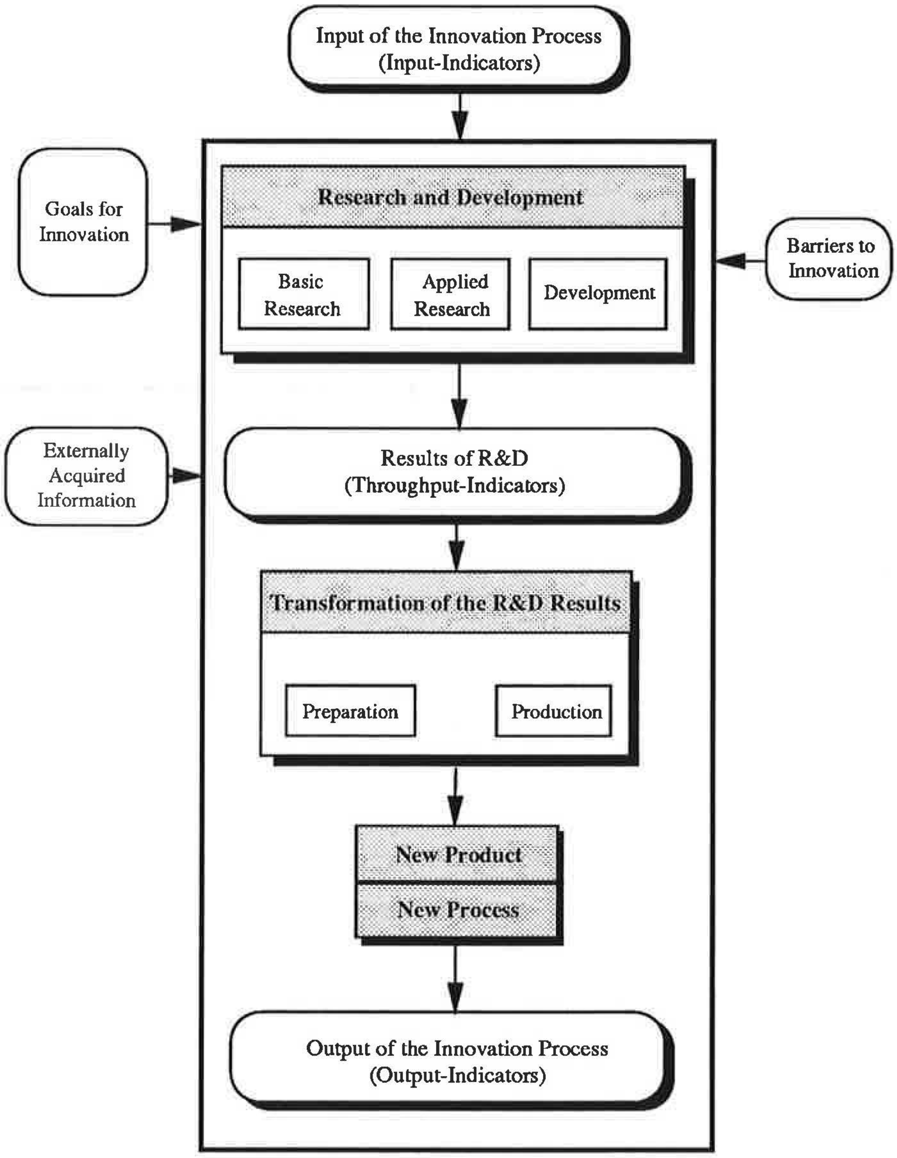
The vast bulk of industrial R&D efforts is directed towards applied research and experimental development, with an emphasis on development (including the design, production and testing of prototype and pilot developments). Both types of activities are important for a manufacturing firm to maintain or enhance its commercial position. Applied research involves detailed engineering applications of the ideas of basic research and other sources and may be defined in this context as that work which is undertaken with commercial objectives in view, in terms of new or improved products, processes or devices. The operational time horizon is medium, the degree of uncertainty moderate and barriers to entry medium, while development activity is being characterised by a short run operational time horizon, a low degree of uncertainty and low barriers to entry (see Howells 1984).

Development and applied research is more widely dispersed among firms where benefits are more intermediate and short term. However, even with development work the sheer costs of certain development programs, for example with the development and testing of new drugs or the development of new aero engines, may restrict such activities to larger firms only.

The dispersal nature of much R&D activity has been analysed by a number of studies (see Malecki 1980, Thwaites et al. 1981, Howells 1984, Thwaites and Alderman 1988). For large multi-site corporations R&D is undertaken usually both on a centralised and decentralised basis. Basic research is carried out in central research labs, applied research at a divisional/regional level and short term development work takes place within each product division in smaller development labs attached to production units (see Twiss 1974).

Although innovative activities are widely considered as crucial for an explanation of economic growth, of relative competitiveness of industries and firms, innovation is a phenomenon which is not easy to measure. In most studies innovation is measured in terms of R&D input, i.e. R&D expenditures or numbers of R&D employees, or R&D output for which numbers of patents are counted. Each of these indicators has its specific shortcomings. R&D figures, whether measured in value or in employment, tell only something about one aspect of the innovation process, the input side. They indicate the

**Figure 2: Input-, Throughput- and Output-Indicators for Characterising the Innovation Process**



budget resources allocated to the R&D process, but not the actual amount of resulting innovations. Patents, as such measure only the inventive output or at best some aspects of the R&D output in terms of how many inventions are administered but reveal little about the innovation output. Not all patented inventions prove to become innovations, and many innovations are never patented. Also differences in propensity to patent between industry sectors and size classes can be observed.

A more fruitful way to characterize and measure the innovation process is to rely on a system of indicators which capture different aspects of the multi-dimensional nature of the process (see Figure 2), namely:

* input indicators, such as R&D figures measured in terms of expenditures and employment,

* throughput indicators on R&D-output indicators, such as patents, and

* output indicators characterising the output of the whole innovation process in terms of new products an production processes.

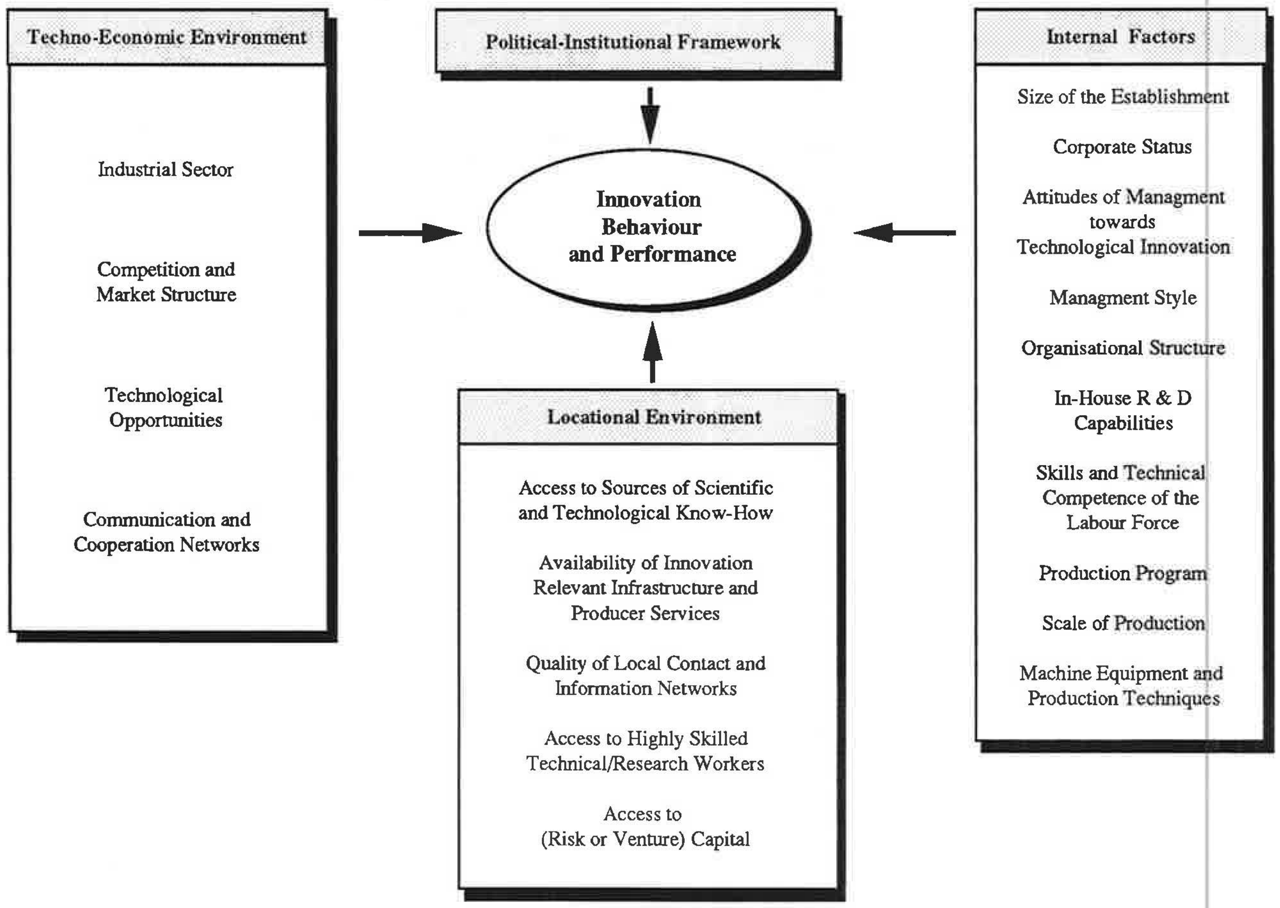
Clearly, it is most difficult to measure the output of the innovation process. In view of conceptual and measurement problems in general innovation counts, based on the concept of subjective innovations, are being used.

## 3. Determinants Likely to Influence Innovation Behaviour and Performance

Any explanation and prediction of technological change has to be based on an understanding of the determinants of such changes. In this section elements from different theoretical contributions and conclusions from empirical research will be mediated into a conceptual framework for analysing determinants to innovation behaviour (see Figure 3).

In assessing factors which influence innovation behaviour and activites it is necessary to go beyond the characteristics of the innovating firm. It is increasingly recognized that the environment in which the firm operates more or less strongly influences - sometimes facilitates and sometimes retards -

**Figure 3: Major Categories of Determinants**



processes of technological change. Such acceleration and retardation effects relate not only to the sectoral, economic and technical environment of the firm, but also to the locational environment (i.e. the region) and to the political-institutional framework in and under which the firm has to operate.

Thus, altogether four major types of determinants may be distinguished (see Figure 3):

* **first**, factors related to the firm´s potential for innovation activities, i.e. the firm´s innovation-relevant internal characteristics,

* **second**, factors related to the firm´s interaction with its locational and/or regional environment, i.e. innovation-relevant locational influences,

* **third**, factors related to the firm´s interaction with its sectoral, technical and economic environment, i.e. innovation-relevant influences of the wider environment,

* **fourth**, factors related to the political-institutional context in which the firm has to operate.

The various factors which might conceivably influence innovation and the introduction of product and process innovations add up to a formidable list. Their importance, of course, varies in relation to the type of innovation (product innovations, process innovations, organizational innovations) considered and their complexity. The most important factors will be discussed in the sequel.

### Internal Factors

Internal factors relating to the behaviour and structure of the firm play an important role in influencing innovation activities and behaviour, as well as in explaining differences in innovation performance.

The relationship between **establishment size** and innovation has been the matter of a long standing debate (see Kamien and Schwartz 1982, Freeman 1982, Galbraith 1985, Hagedoorn 1989, etc.). It is clear that the question what size of firm is most appropriate to stimulate innovation is not only of theoretical interest, but also important for the design and implementation of innovation policies.

Some scholars like Galbraith (1985) argue in the Schumpeterian tradition that large size is a prerequisite for economic progress via technological change and emphasize the pre-leading role which large companies play in technological change. This view is largely based on the rationale that larger firms show a greater ability to raise capital necessary for innovation projects and to spread risks over a portfolio of projects. They have a greater capacity to manage information and to maintain large R&D facilities, and can afford the managerial and technical specialists which are often needed to make an innovation sucessful. In contrast, small enterprises not only lack risk capital, but also risk ideas due to substantial information problems. They have difficulties in acquiring existing knowledge and information adequate to their needs. Market research and effective market observation and penetration is often beyond their capabilities.

The supremancy of large firms in innovation has been questioned by many. Scholars like Rothwell and Zegveld (1982) stress the specific role of smaller firms, especially of high tech firms, in the process of technological change and point to several comparative advantages in innovation which may be ascribed to them, their ability to react quickly to keep abreast of fast-changing market requirements, their lack of bureaucracy, their able marketing for particular niches, their great flexibility of internal communication networks and their ability to adapt to change in external environments (see also Rothwell 1986, Sweeney 1983). But also several disadvantages are mentioned such as lack of qualified R&D personnel, shortcomings in external communication, constrained financial resources, lack of management skills and inability to take advantages of government measures.

Advantages and disadvantages associated with small and large firms in innovation suggest a priori that comparative advantages in innovation are unequivocally related neither with large nor with small scale. There seems to be some sort of increasing consensus that small (especially technology-based new) firms play an important role in the earlier stages of a particular technology, followed by an increasing importance of large firms in the further development of a technology. At a particular medium size both innovative input and output tend to rise less than proportionally to size. Thus, there are good reasons to assume a non-linear U-shaped relationship between innovation and firm size, with both large and small firms sharing greater innovation activities, while medium-sized firms are lacking behind in innovation generation (see Pavitt et al. 1985, Fischer and Menschik 1990, inter alia). But there is a large intersectoral variation in the patterns.

Recent empirical studies suggest that the **organisational** or **corporate status of the establishment** strongly influences its potential to innovate (see Malecki 1980, Thwaites et al. 1981, 1982, Fischer and Menschik 1990). With respect to the corporate status four major types of establishment may be distinguished: single-plant independent enterprises and those forming part of a multi-plant enterprise. In contrast to single-plant enterprises multi-plant corporations operate in a multi-local network. Such establishments having access to the facilities of finance, specialised labour, R&D expertise available through a multi-plant enterprise display generally higher levels of innovation than single-plant independent enterprises which are more resource constrained.

But there are differences in innovation behaviour among multi-plant establishments. Those establishments with higher organisational status (such as group headquarters and divisional/regional headquarters) - accompanied by higher levels of functional responsibility and complexity - within a multi-plant enterprise exhibit a higher propensity to innovate than branch plants which tend to lack all the main catalists for innovation (such as in-house R&D, especially research, finance, corporate planning and decision making) to a greater or lesser extent. The decision on the introduction of new products or major process machinery is largely a matter for centralised decision making (see Malecki 1990).

Innovative behaviour is to a large extent dependent on the **attitude of management towards technological innovation**. Active firms where management aims at achieving both technological and market leadership through taking the risk to grasp the techno-economic opportunities offered (offensive innovation strategy), display a much greater propensity to innovate than passive firms, where management just reacts to direct market pressures such as excess demand or increasing competition or falling profit markets (defensive or absorptive strategy). Defensive strategies do not necessarily imply a complete ignorance of innovation acitvities. Large multi-product enterprises may be aggressive and innovative with respect to some product lines and at the same time rather slow and defensive in others. This may be expected because people with different talents, goals, levels of competence and attitudes contribute to the firm´s decision making (Thomas and Le Heron 1975). Aggressive and innovative management attempts to cope with technical, organisational and economic change through two parallel concepts: know-how intensive products and flexible automation. The concept of management aggressiveness, however, is not easy to operationalise in empirical research and, thus, has remained largely a qualitative explanation of residuals from innovation patterns.

Successful product innovation tends to be associated with an open, horizontal **management style**, one which is organic rather than mechanistic, especially with respect to R&D. Within such a framework middle management can function most effectively in stimulating innovations. But there is no doubt that success seems to be associated with the presence of one or two key persons (business innovator, product champion, technical innovator) in the firm who are enthusiastically support the innovation (Rothwell 1977). Moreover, the firm is more likely to innovate if it recruits and trains well educated personnel who are encouraged to push technology forward in the organisation.

Other specific factors which most likely influence the level of innovation activities are the **status and scale of in-house R&D**, the **organisational structure** for dealing with the process innovation,the **skills and technical competence of the labour force**, the **pattern of the production program** and the **scale of production**, **machine equipment** and **production techniques,** and a whole host of other factors which are generally of minor importance, but could be of paramount significance to an individual firm.

### Factors Related to the Locational/Regional Environment

Though economists have undertaken numerous studies on technological change and innovative behaviour, they have largely ignored the regional dimension of the innovation process. The regional dimension relates to the question whether differences in innovation behaviour and performance which have been observed in several studies (see Thwaites et al. 1981, 1982, Ewers et al. 1980, Fischer and Menschik 1990, and others) regardless of their partly industry specific and/or size specific nature may be explained by properties of the spatial environment in which firms have to operate.

This issue is related to the industrial milieu in general and to those factors in particular which are associated with

* the **access to information and technological know-how**, such as science and technologically oriented universities, research institutions, knowledge centres, national or international repositories of information such as libraries, patent offices and data bank systems, the density and quality of local contact and information networks, and

* **channels of supply for innovation**, such as information services, the availability of higher skilled labour force, the availability of finance which is an essential ingredient in enterprises unable to produce adequate funds from internal sources, although opinions diverge whether the existence of local venture capital institutions actually is a crucial factor compared to its national availability (see Ewers et al. 1980).

The local technical infrastructure may be considered as a reflection of the local industrial structure.These factors are likely to be especially significant in the case of small firms, particularly single-plant independent firms which generally lack comprehensive in-house R&D capabilities, while larger firms and multi-plant establishments are less dependent on their local and regional environments. Branch plants are provided with resources and information via corporate contacts and linkages. The major bottlenecks for small firms in peripheral and rural regions which are poor in terms of the environmental complexity needed for innovations are found in the area of human capital, information provision and risk capital. Large firms and particularly multi-size firms can overcome these limitations more easily.

## Influences of the Wider Environment

In general the **industrial sector** in which a firm operates is considered as a major factor influencing its potential to innovate (see Oakey et al.1980, Fischer and Menschik 1990). Closely related to the industrial sector are other determinants such as technological opportunities to innovate, and market pressure and structure. **Technological opportunities** may be defined as the extent of basic scientific knowledge in industry (see Dosi 1984). Evidently technological opportunities vary with time and among industries. New growth industries like electronics, chemicals and allied industries, aero space have more technological opportunities to innovate than other more mature industries like textiles and clothing.

The relationship between **market structure** and innovation has been the object of much theoretical and empirical debate, Kamien and Schwartz (1982) have summarized the Schumpeter-inspired hypothesis as follows: Innovation is greater in monopolistic markets than in competitive ones, first because a firm with monopoly power can prevent imitation and thus can capture more profit from an innovation, and second because a firm with monopoly profits is better able to finance R&D. Galbraith (1985) asserts that competitive markets tend to be not very suited for innovation because diffusion and imitation destroys the profit of innovation and imitators are quick to take advantage of the inventive activities of the original innovators. If one looks at the empirical work on the relationship between market structure and innovation one can find some consensus, but only at level of high generality, in so far that market concentration has a favourable impact on innovation in certain industry-specific situations (for example in mechanical and electronic/electrical industries manufacturing consumer goods). How much concentration, however, is advantageous remains to be determined (Hagedoorn 1989).

Finally it has to be stressed that efficient **communication and co-operation links with the techno-economic environment** have been found to be important for successful innovations, especially in current times of market saturation, market fragmentation and increasingly volatile demand conditions. Certain risks of innovation can be reduced through sub-contracting arrangements for components that require specialised knowledge or equipment to produce. In recent years new forms of co-operation between large and small high-tech firms can be observed in pursuit of dynamic complementarities. The smaller enterprises can operate more flexibly and find their way - via the large firms - to the market place. High-tech enterprises are important elements in the process of knowledge-transformation (Zegveld 1987).

### Factors Related to the Political-Institutional Context

Among the determinants the general framework within which the economic process takes place, the laws and rules and regulations under which companies operate in a market oriented economy; the attitudes towards technological change of the public; the way in which the scientific and technological activities of relevant governmental institutions are organized and managed; the amount and character of R&D in the universities; etc. play an important role (see Mansfield 1968). Part of the framework are the general conditions for a creative process of innovations in society and economy, government policy towards science and technology and innovation. The attitude of the government to technological change can have far-reaching influences on innovation behaviour and processes via various policy tools such as

* the provision of financial, manpower and technical assistance, including the establishment of a scientific and technological infrastructure,

* the demand for innovative products, processes and services by central and local government purchases and contracts and by

* measures (such as taxation policy, patent policy and regulations) which establish the legal and fiscal framework in which industry operates (see Rothwell 1983).

## 4. The Logit Model Approach to Analysing Innovation Behaviour and an Empirical Example

Little is known how the determinants discussed in section 3 interrelate with each other and influence innovation activities, measured in terms of product and/or process innovations introduced in a certain period of time. A statistical modelling approach to deal with this issue has to fulfill at least the following two requirements:

* **first,** the determinants to innovation behaviour discussed in section 3 have to be taken into account **simultaneously**, and

* **second**, the statistical modelling approach has to enable to assess the effects of **mixed explanatory variables** (i.e. metric and discrete variables) on a **dichotomous response variable**, because due to measurement problems the output of the innovation process is measured in terms of the introduction of product and process innovations by using a dummy variable which takes the value one or zero depending upon whether the firm does or does not introduce an innovation in the considered time period.

If the conventional regression model approach is extended to deal with a discrete response variable, several readily apparent problems will arise. First, the conventional regression model with a discrete response variable will violate the homoscedasticity assumption of the classical linear regression model and therefore the problem of heteroscedasticity will be present which does not result in biased or inconsistent parameter estimates, but in a loss of efficiency. Moreover, this problem gives rise to biased estimates of the variances of the coefficients leading to serious problems if conventional inferential tests are used. Second, the model may generate predictions which are seriously deficient because the predictions may be outside the meaningful range of probabilities (see Wrigley 1985 for further discussion).

There are several potential modelling approaches which fulfill the above mentioned requirements and whose predictions are constrained to lie within the range of 0 and 1. The most convenient one is based upon the cumulative logistic probability function and is referred to as the **logistic regression or logit model**. In our case of a dichotomous response variable, introduction of an innovation (yes: j=1, no: j=2), the logit model takes the following form

$$p_i\ (j=1) = \exp(\mathbf{z}_i' \beta) / (1 + \exp(\mathbf{z}_i' \beta)) \qquad i \in I \quad (1)$$

with

$$\mathbf{z}_i' \beta = \beta_0 + \sum_{k=1}^{K} \beta_k Z_{ik} \qquad i \in I \quad (2)$$

$$\mathbf{z}_i = (1, Z_{i1}, Z_{i2}, \ldots, Z_{iK}) \qquad i \in I \quad (3)$$

$$\beta' = (\beta_0, \beta_1, \beta_2, \ldots, \beta_K) \qquad (4)$$

where $p_i$ (j=1) represents the probability that any innovation was introduced at plant i, $i \in I$ (set of industrial plants), between a certain period of time $(t_1, t_2)$, given the values of the K explanatory variables, $Z_{ik}$, $\beta$ denotes an unknown ((K+1), 1)-parameter vector which has to be estimated.

Estimation of the parameter coefficients can be done by means of the maximum likelihood estimation procedure. Given that the response category choices are considered as independent drawings from the binomial distribution the likelihood function of (1) is given as

$$L = \prod_{i=1}^{I_1} p_i(j=1) \prod_{i=I_1+1}^{I} p_i(j=2) =$$

$$= \prod_{i=1}^{I_1} \frac{\exp(x_i' \beta)}{1 + \exp(x_i' \beta)} \prod_{i=I_1+1}^{I_1} \frac{1}{1 + \exp(x_i' \beta)} \qquad (5)$$

where the choices in the data set are ordered so that $I_1$ choices of the first response category came prior to the $I$-$I_1$ choices of the second response category.

A maximum likelihood estimation is obtained at any point where $\partial L / \partial \beta = 0$, since $\partial^2 L / \partial\beta \, \partial\beta'$ is negative semidefinite implying that L is concave in $\beta$, then L has a unique maximum in $\beta$, provided that one exists. The conditions for the negative definitivenes and non-singularity of the matrix of second derivatives are given in McFadden (1974). Usually, these conditions are likely to hold, and for the maximum likelihood estimate to be unique, if the sample is of reasonable size. Under general conditions the maximum likelihood estimators are asymptotically efficient and normally distributed.

For the goodness of fit of the model in question a pseudo-$R^2$ , the likelihood ratio index

$$\rho^2 = 1 - \log L(\hat{\beta}) \;/\; \log L(\hat{\beta}^H) \qquad (6)$$

can be used, where $\log L(\hat{\beta})$ denotes the value of the log likelihood function at its maximum and $\log L(\hat{\beta}^H)$ that of the model defined by the null hypothesis. This measure is zero when $\log L(\hat{\beta}) = \log L(\hat{\beta}^H)$ and $\rho^2 = 1$ when the model is a perfect predictor. A major shortcoming of this measure, however, lies in the fact that it will always increase or at least stay the same whenever new explanatory variables are added. For this reason the adjusted rho-square bar defined as

$$\bar{\rho}^2 = 1 - (\log L(\hat{\beta}) - (K+1)) \;/\; \log L(\hat{\beta}^H) \qquad (7)$$

may be used with (K+1) denoting the number of parameters. Another informal goodness-of-fit measure refers to the percentage of correct ex-post predictions (the so-called prediction success) which counts those observations for which the model predicted the same choice (introduction of an innovation or not) as was observed.

The logit model approach discussed above will now be illustrated using an example of a wider research project on innovation activities in Austrian manufacturing industry. Data on the innovation process were obtained through an interview survey of senior executives of 185 manufacturing establishments and enterprises within a limited number of manufacturing industries (iron and steel, metal products and machinery industries, electrical products and electronics industries, textiles and clothing industries) in different regional environments (the core metropolitan region of Vienna and its immediate hinterland, a traditional iron-based industrial region and a peripheral region) (see Fischer and Menschik 1990 for more details). Different survey designs have been used, in the core of the metropolitan area and its immediate hinterland stratified samples by size and industrial sector, whereas complete surveys were made in the other two regions. Logit models were used to explain two dichotomous measures of innovation output: process innovation (i.e. whether any new process was introduced at the plant between 1982 and 1986 or not) and product innovation (i.e. whether any new product was introduced at the plant between 1982 and 1986 or not).

In the case of the product innovation some of the potential determinants of variation in rates of technological innovation were - according to the conceptual model in Fig. 3 - believed to be

* **internal factors** such as establishment size, organisational status, expenditures for basic and applied research, innovation expenditures for production preparation, patent/licence activities, and

* **environmental influences** such as regional location, industrial sector, market concentration, supplier relations with the EC and Switzerland, contacts with external know-how institutions.

Most of these potential explanatory variables - except establishment size measured in terms of employment and the two types of expenditure variables - were categorical in nature. Regional location was a variable with four categories (core of the metropolitan area of Vienna and its immediate hinterland, a traditional iron-based industrial region and a peripheral region) representing four major types of regional environment showing quite different environmental complexity. Industrial sector and organisational status were trichotomies representing three major categories of industries with quite different technological opportunities (iron and steel, metal products and machinery industries; electrical products and electronics industries; textiles and clothing industries) and enterprise type (single-plant enterprise, head quarter and branch plant). Patent/licence activities (yes,no), market concentration (high versus low degree), supplier relations with the EC and

**Figure 4: Product Innovation Model: Introduction of a New Product (1982-1986)**

Switzerland (strong, weak) and contacts with external know-how institutions (yes, no) were dichotomies.

The model was fitted using Börsch-Supan´s HLOGIT computer program. The fit obtained is satisfactory in terms of $\rho^2$ and $\bar{\rho}^2$. The parameter estimates are shown in Fig. 4. The results indicate that the odds of product innovation at a plant are significantly (0.5-level) increased by two major determinants, a high degree of market concentration and a reasonably high allocation of innovation expenditures to the stage of production preparation. There is also a positive associative effect of small scaled establishments (1-19 employees) and contacts with institutions providing external know-how. This interaction effect which is statistically significant at the 0.10 level points to the importance of information networks for small-sized firms in the innovation process.

However, the odds of product innovation are significantly reduced if

* it is a single-plant enterprise, and if
* it is a single-product company located in a peripheral region.

The relationship between product innovation and establishment size is weak and statistically insignificant. The same is true for expenditures devoted to the early stages of the innovation process. Other factors such as support by innovation policies, degree of product diversification, scale of production, supplier relationships to the EC and Switzerland, export orientation, and skills of the labour force were found to play no significant role in the context of the study.

## 5. Summary and Conclusions

Technological innovation is a complex techno-economic process which involves an extremely intricate web of interactions, both intra-firm and between the firm and its environment. One of the major problems one faces in innovation research refers to the way in which this complex nature is measured. There is no easy or universally accepted method of measuring innovative activities which contribute to the quality, efficiency and costs of products and production processes. Different indicators have been applied in empirical research, such as patents, R&D employment or expenditures. But each of them has its specific shortcomings.

R&D indicators whether, measured in employment or value, measure only the R&D input. Certainly, R&D is a major component in the innovation process. But innovation is not simply a matter of R&D. It also involves inputs from the production and marketing departments throughout the course of an innovation project. Otherwise, there is a danger that the final product - while satisfactorily from the technical point of view - may be difficult to manufacture without a considerable degree of modification. Moreover, the relationship between R&D-input and innovation process is not deterministic in nature.

The other innovation indicator which is widely used are patents. Patents measure some sort of the R&D output in terms of invention. This indicator has the shortcoming that not all patent inventions become innovations, and many innovations are never patented. The output of the innovation process has to be measured in terms of the quantity and quality of product, process and organisational innovations. To measure the quality and content of innovations is a task which is far from easy. Further research is needed to arrive at satisfactory measurement concepts.
Another important issue discovered in the paper relates to the question of identifying the key determinants to innovation. It is clear that this question is not only of theoretical relevance, but also very important with respect to the design and implementation of governmental innovation policies. An attempt has been made to categorize the different factors influencing innovation. Based on theoretical contributions and conclusions from empirical research the most important ones had been identified and integrated into a conceptual framework which might be used to analyse the innovation output and various a priori hypotheses within the logit model approach outlined. The flexibility and usefulness of this statistical has been illustrated by means of an example.

***Acknowledgement:*** *The author acknowledges a grant from Comitato Nazionale Scienze, Tecnologie dell´Ambiente ed Habitat del C. N. R. (Italia).*

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