SERIE RESEARCH MEMORANDA

TECHNOLOGICAL DEVELOPMENT

AND

REGIONAL LABOUR MARKETS

Peter Nijkamp

Piet Rietveld

Researchmemorandum 1986-38 November 1986

VRIJE UNIVERSITEIT

FACULTEIT DER ECONOMISCHE WETENSCHAPPEN

A M S T E R D A M

Technological Development

and Regional Labour Markets

Peter Nijkamp
Piet Rietveld

Department of Economics
Free University
Amsterdam

1. Introduction

The present interest in technological development and its consequences for employment is not an entirely new issue. The importance of this theme has already been recognized by classical economists such as Adam Smith and David Ricardo.

Within the classical school, no common opinion did exist on the influence of technological change on employment (see Freemand and Soete, 1985). It was commonly accepted that technological development in certain sectors would usually lead to labour saving investments and thus to a loss of employment in the sectors concerned. Differences of opinion however existed on the size of compensation effects. Some authors argued that a sufficient compensation could be realized by employment growth in machinery producing sectors, while besides the ensuing price decrease would stimulate demand in all sectors, which has also a positive effect on employment. Others were more pessimistic on the importance of the compensation effect: there is no guarantee that the market can fully absorb the increased production resulting from technological change. In addition, capital supply might be insufficient to absorb displaced labour in compensating sectors.

The mainstream of neo-classical theory was more positive on the unemployment effects emanating from technological development. Adaptation to technological development was assumed to take place via flexible wages, prices and interest rates, leading to a clearing of all markets, including the labour market. Thus, unemployment due to technological development cannot be a major long-term problem.

This conventional neo-classical approach to technological development is unsatisfactory for a number of reasons (see Hoogteijling et al., 1986). First, technological development is studied as a smooth, continuous process. Consequently, adaptations are relatively easy to be realized. The sudden revolutionary introduction of new production processes or products is ruled out in this way. Second, technological development is assumed to be exogenous. Thus, one can only study the consequences of technological development; its very causes remain untouched. Third, production processes and products are assumed to be fixed; no life-cycle effects are taken into account. Fourth, markets are assumed to be perfect. As a consequence no attention is paid to the differential effects technological development may have on the skills required for the jobs created and the skills of those who loose their jobs. Similarly, the differential impacts on regional labour markets are ignored. Fifth, no attention is paid to diffusion processes of innovations, so that factors stimulating or hampering their adoption cannot be studied. Finally, a rather one-sided attention has been given to process innovations as opposed to product innovations. This is understandable since it is not easy to incorporate new products in theories of consumer demand (see Lancaster, 1971). One must be aware however, that the employment consequences of product versus process innovations may be rather different.

Schumpeter's (1934) theory on technological development covers some of the points made above. Schumpeter maintains that innovations do not occur in a smooth way; innovations are concentrated in time and in certain sectors. Thus, innovations give rise to serious adaptation problems. For the successful introduction of innovations, a large reallocation of capital and labour is necessary. Unemployment problems will according to Schumpeter emerge, but not during the first phases of the introduction of innovations. Schumpeter expects that in the first phases, technically progressive sectors will experience an employment growth, which can compensate for the slowdown in other sectors, resulting from the diversion of capital. However, when at a certain time market satiation will occur in the originally progressive sectors, a depression will come into being, leading to serious unemployment.

The long and serious stagnation in the world economy, which started in the 1970s has greatly stimulated interest in Schumpeter's approach (see for instance Freeman, 1984). In the present paper, we will survey some of the recent research results on technological development and innovation with special attention to the implications for regional labour markets. Section 2 will be devoted to the generation of innovations. In sections 3 and 4 diffusion of innovations will be discussed. In these sections, the labour market aspects relate to labour as a determinant of innovative activity. Thus, the role of qualified labour in the intensity and spatial distribution of innovative activity will be discussed. Section 5 will be devoted to the other side of the coin, i.e., the (regional) employment impacts of technological change.

2. The Generation of Technological Development

According to the definition of Freeman (1974), an innovation is accomplished with the first commercial transaction involving a new product, process, system or device. Innovation is preceded by the stage of invention: the generation of an idea for a new product, process, system or device. There is no guarantee that each invention will ultimately lead to an innovation: many new ideas may remain unused since they cannot be applied in a profitable way. As shown in Table 1, there are two different ways of measuring inventive and innovative activity, i.e., via the inputs and via the outputs.

		measurement according to	
		input	output
stage	invention	research efforts	realized patents
	innovation	research and development efforts	realized innovations

Table 1. Technological development according to stage and way of measurement.

The usual way of measuring the output of inventive activities is the number of patents realized in a certain period. This way of measurement is not without problems, however, since patents may be rather different in scope, and different countries may follow different patenting policies. Besides not all inventions are patented and there are also differences in patent ratios for different firm sizes. In practice, it appears that there is no other way of getting data on the output of inventive activities.

Concerning the inputs of inventive activities, Stoneman (1983) mentions that the share of R & D expenditures devoted to pure and applied research is usually relatively small, the larger part being used for development activities. Since development is a typical activity in the innovation state, it appears that from the viewpoint of inputs, innovation is more demanding than invention.

Stoneman (1983) finds that inventive activity, as measured by realized patents, is less influenced by market developments than innovation activity. Further, it appears that a considerable part of patents is realized in small firms and outside the business sector. Thus, R&D in large firms is not the sole important source of inventions. However, it appears that R & D departments of large firms do play a very important role in the next phase: innovation.

Given the sometimes rather loose connection between invention and innovation, it is probable that the spatial distributions of inventive and innovative activities are different. It seems reasonable to conjecture that inventions have a more equal spatial distribution than the usually rather unequal distribution of innovations (see later in this section). This would imply that spatial centres of innovation tend to be net-importers of inventions by sucking up and selecting new ideas arising anywhere (see also Mouwen and Nijkamp, 1986). Next, these inventions are transformed into marketable products and processes to be exported (diffused) to anywhere.

The major indicator of innovation from the viewpoint of inputs is R&D. Firms may have different motivations for being engaged in R&D (see Freeman, 1974). Offensive R&D is aiming at achieving market leadership by being ahead with competition. Defensive R&D is undertaken to improve existing products and processes to counter the attack of offensive rivals in the market. Finally, protective R&D is undertaken to develop products or processes which will only be marketed if the firm is forced to do so by rivals. Note that the latter kind of R&D does not necessarily lead to commercial transactions and hence does not necessarily fall under the heading of innovation.

Where does R&D take place? Malecki (1981) finds that in industrial multiplant firms, R&D departments tend to be located near the corporate headquarters. This results in a strong bias of R&D activity towards urban centres. For example, it is found that in 1965 60.1% of R&D departments in industry were located in the ten largest SMSAs of the USA, whereas only 29.7% of the total population lived there.

Malecki finds that, among others, the following factors exert a significant influence on R&D activities per region: presence of research oriented universities, and number of scientists and engineers in the region. The first result implies, that social overhead capital has a significant influence on innovation activity in a region. The second result means that supply of qualified labour is an important determinant of the location of R&D activities. Thus, a mutual relationship exists between regional labour markets and technological development. On the one hand, regional labour markets are influenced by technological development; on the other hand, regional labour markets have an influence on the location of R&D efforts.

Malecki finds that the distribution of R&D among regions is gradually becoming more equal. Between 1965 and 1975, the share of industrial R&D departments in the ten largest SMSAs declined from 60.1% to 52.4%, whereas the population share in the same area only decreased from 29.7% to 28.7%. A closer look at the data reveals that spatial shifts in R&D occur at two levels. First, at the interregional level, a shift takes place from the Frostbelt to the Sunbelt. Second, at the intraregional level, a redistribution tendency can be observed where small SMSAs near large cities have increased the R&D activity, despite declines in the nearby larger SMSAs.

Several of the findings on the USA are in line with research results in Europe. For example, for the U.K., Goddard and Thwaites (1986) report very high levels of R&D in smaller cities subordinate to Greater London, as opposed to smaller cities elsewhere, especially in the North. For the Netherlands, Bouman and Verhoef (1986) find an urban bias in the location of high technology employment. For the F.R.G., Ewers (1986) reports that in highly agglomerated areas the share of firms having their own R&D is twice the share in rural areas.

Storper (1986) points at the phenomenon that often innovative activities are not located in cities at the top of the existing urban hierarchy, but rather in medium sized cities, not too far away from large cities. He explains this by the relative freedom to locate innovating firms: when they make big profits they do not need to worry on costs connected to location. They have factor attracting power since they are able to offer high prices for the production factors they need. Storper recognizes that this factor attracting power is limited, however, especially since the supply of highly skilled labour is not so price elastic that highly skilled persons can be induced to migrate anywhere. This again underlines the importance of regional labour supply as a determinant of innovative activity.

The product life cycle theory, formulated by Vernon (1966) states that along the cycle followed by a product from innovation, via expansion to maturity and market saturation, the production process is becoming more and more standardized. The average level of required skills is continuously decreasing during this process. These tendencies have implications for the location of production during the various phases (see e.g. Erickson, 1981). In the innovative phase, firms are attracted to existing agglomerations, among others because of the need of skilled labour. In the expansion phase, the most appropriate location is near large agglomerations: skilled labour is still needed, but the need for sufficient space is becoming urgent. In the maturity phase, the most appropriate location is in the periphery: there is no extensive need of skilled labour. Low prices of labour and land are important considerations here (see Johansson and Karlsson, 1986).

It is interesting to investigate the implications of the product-cycle for urban development. Of course, urban development depends on more than the behaviour of industrial firms only. The tertiary sector, households and the government also play an important role. Nevertheless, the industrial sector remains important in the cities and it is promising to consider the possibility of linking urban developments to product life cycles in industry. A well defined typology of stages of urban development is given in the CURB project (Van den Berg et al., 1981): urbanization, suburbanization, desurbanization and reurbanization, each stage defined by means of certain configurations of population growth differentials of urban core, urban ring and total functional urban region. Little effort is made in the CURB project to indicate the forces which determine the process of metropolitan growth and decline. Camagni (1986) presents evidence for Northern Italy, which suggests that there is a very close relationship between city life cycles and product life cycles. This link between technological and urban development is a promising subject of further research.

3. Diffusion of Innovations

When a new product or process has been developed which is superior to its predecessors, one might expect instantaneous adoption. In reality, instantaneous adoption does not occur, however. There are several reasons for this.

First, there may be a problem of information. Innovations cannot be adopted by potential users as long as they do not know about it. The speed of innovation adoption will depend on the ways in which information is exchanged. Second, risk may play a role in innovation adoption. In average terms, a new technology may be superior to existing ones, but when potential adopters are risk-aversive, they may decide not to adopt because in incidental cases, the innovation may yield very negative results. Third, the profitability of an innovation may only be positive for part of the potential adopters. This often occurs when the potential adopters are very heterogenous, for example, according to scale of operations. Fourth, psychological inertia may play a role. Often, firms need a certain amount of stress before the decision is taken to change an existing strategy. Fifth, adoption maybe delayed because of lack of complementary inputs. Sixth, institutional factors may play a role in speeding up or delaying adoption decisions. For example, brach plants may have a different behaviour, compared with independent plants. Seventh, supply constraints may play a role. The producers of the new product or process cannot instantaneously meet the demand of all potential users because of limited production capacity.

The above reasons are not mutually exclusive; several of them may be relevant at the same time. In this section we will further discuss the role of these factors in innovation adoption. Special attention will be paid to their relevance for the relationship between technological development and regional labour markets.

When discussing the various factors influencing innovation adoption, one will find that adoption can be studied at both the individual and the aggregate level. At the individual level, the decision to innovate is often treated as a binary variable (yes=1, no=0). Adoption intensities may vary, howevere, so that a formulation in terms of a continuous variable on the inverval 0 to 1 is often more adequate. Also at the aggregate level one will usually end up with such a continuous variable on a limited interval. This may give rise to rather special estimation problems (see Maddala, 1983), as will be discussed in section 4.

3.1. Adoption and Information

Epidemic models have been devised for studying the spread of infectious diseases in a population. These models also appear to be relevant for analysing the diffusion of information on innovations. The speed of diffusion depends among others on the communication network, frequence of contact and the extent to which receivers of the information tend to adopt the innovation. When one makes the simple assumption that the probability of contact between every pair of persons is the same, that everybody is a potential adopter, and that the frequency of contact as well as the acceptation behaviour remain unchanged during the process, one arrives at the well-known logistic curve (cf. Stoneman, 1983):

$$p(t) = 1/[1+ \exp(a-bt)] \qquad (b>0) \qquad (1)$$

where t is time and p(t) is the fraction of adoptors at time t. The parameters a and b determine the starting point and the rate of increase of adoption, respectively. It is easy to check that $p(t)=0$ for $t\to-\infty$ and $p(t)=1$ for $t=\infty$. Thus, at the end everybody has adopted the innovation.

The assumptions made to reach the logistic curve are rather simplistic. One way of making the information diffusion theory more realistic is by taking into account the role of distance (cf. Hagerstrand, 1968). Contacts between persons living near each other are much more frequent than contacts between persons further away. Thus, Abler et al. (1972) formulate the alternative that the fraction of adopters does not only depend on time, but also on the distance from the place where the innovation was done. One way to do this is by assuming that the parameter a in (1) is distance dependent: $a=a_1+a_2d$, where $a_2>0$. Also, the spread of adoption could be made distance dependent: $b=b_1+b_2d$. Abler et al. (1972) mention several cases where indeed the areas further away from the center of innovation are adopting later than areas near the center of innovation. Another pattern of diffusion may arise when an urban hierarchy exists. In that case, leap frogging will occur, high ranked distant cities being earlier adopters than nearby low ranked places.

It may be concluded that according to the information diffusion approach, peripheral areas tend to deal with less advanced products and processes compared with central innovative areas. This has consequences for the volume and composition of labour demand in peripheral regions.

3.2 Adoption and Risk

The relationship between innovation adoption and risk can be analysed as follows (see Stoneman, 1983). Consider two technologies (1= new, 0= old), the net returns of which are subject to a degree of uncertainty: they have distributions with μ_{1t} and μ_{0t} and variances σ^2_{1t} and σ^2_{0t}, respectively. If a firm would only take into account mean net returns, it would just choose the technology with the highest mean. However, when also risk is taken into account, a mixture of technologies may arise, which can be seen as follows.

Let α_t be the proportion of output produced with the new technology at time t. Then the mean and variance of a mixture of technologies are respectively equal to:

$$\begin{aligned} \mu_t &= \alpha_t \mu_{1t} + (1 - \alpha_t) \mu_{0t} \\ \sigma_t^2 &= \alpha_t^2 \sigma^2_{1t} + (1 - \alpha_t)^2 \sigma^2_{0t} + 2 \alpha_t (1 - \alpha_t) \rho \sigma_{1t} \sigma_{0t} \end{aligned} \qquad (2)$$

where ρ is the correlation coefficient between the returns to old and new technologies.

Assume that the evaluation scheme of the firm is:

$$U = \mu + b\sigma^2/2 \qquad (3)$$

If U is maximized for each period separately, the optimal share of new technology is:

$$\alpha_t^* = \frac{(\mu_{1t} - \mu_{0t})/b + \sigma^2_{0t} - \rho\sigma_{1t}\sigma_{0t}}{\sigma^2_{0t} + \sigma^2_{1t} - 2\rho\sigma_{1t}\sigma_{0t}} \qquad (4)$$

where a^*_t must fall between 0 and 1.

An important determinant of the time path of α^*_t is the uncertainty about μ_{1t} and σ^2_{1t}. As the firm gets experience with the new technology, it may learn in a Bayesian way about the actual values of μ_{1t} and σ^2_{1t}. Thus, a continuous change of the perception of the new technology will occur, not necessarily leading to an increasing use of it. In case of overoptimistic perceptions on the new technology at the beginning, (4) also allows for a decrease of α^*_t.

The above reasoning applies for one firm only. It can be extended to an aggregate analysis of the role of risk in innovation adoption. In that case one needs information about the distribution among firms in their attitude to risk and in the net returns they can achieve.

The learning and risk approach discussed above may have spatial implications. For example, when firms do not only learn from internal experiences, but also from neighbouring adopters, firms in areas with many companion adopters are better informed about the new technology than those in other areas, which may speed up the rate of innovation.

The attitude towards risk may display spatial variations due to variations in the availability of credit facilities (e.g., in developing countries). Spatial concentrations of certain cultural- ethnic groups with specific attitudes towards risk and entrepreneurship may also be mentioned in this respect.

3.3. Adoption and Profitability

Leaving the problem of risk aside (section 3.2.), profitability plays a role in innovation adoption. Why do not all firms instantaneously adopt a new technology, if this is more profitable than an old technology? Evidently, there is a high degree of heterogeneity among firms, so that, when a new technology is more profitable for some firms, it is not necessarily more profitable for all firms. For example, profitability depends on relative prices, and firms in different regions may face different relative prices.

Scale of enterprise is also an important determinant of profitability. For example, David (1969) assumes that the new technology has higher fixed costs and lower variable costs than the old technology. In that case, the scale of production must exceed a certain critical level before adoption is profitable. To arrive at innovation adoption as a gradual process, an additional assumption must be made on the development of the relative price of the new technology. David assumes that it is decreasing at a constant rate. Thus, the diffusion starts with the largest firms, the shape of the diffusion path being determined by the shape of the distribution of firms according to size.

Another determinant of profitability is competence. To operate a new technology, often highly skilled staff is necessary. Similarly, in the case of product innovation, a firm's competence in marketing must be sufficient to make the adoption profitable. In a study of the adoption of various types of process and product innovations for Swedish firms, Johansson and Karlsson (1986) find that the level of competence of staff plays an important role.

There are several spatial implications of the profitability approach. Given the existence of interregional differences in relative prices, one arrives at interregional differences in profitability, and hence at interregional differences in innovation adoption. Thus, one may expect a low rate of adoption of new capital intensive technology in regions where low skilled labour is cheap due to abundant supply. Conversely, in regions with a small supply of low skilled labour, the adoption of a new labour saving technology will be relatively fast. Government policies influencing relative prices may also play a role. Goddard and Thwaites (1986) note that the relatively fast adoption of new technology in peripheral regions in the U.K. is probably due to regional capital subsidies.

A second spatial implication of the profitability approach is that interregional differences in the size distribution of plants will give rise to interregional differences in the rate of adoption.

The third spatial implication of the profitability approach concerns the level of competence of the labour force. As indicated by Johansson and Karlsson (1986), a low level of supply for skilled labour will give rise to a low rate of adoption.

3.4. Adoption and Psychological Inertia

One way of analyzing behavioural aspects of innovation adoption is via the concept of X-inefficiency (see Leibenstein, 1978). The basic idea of X-inefficiency is that persons and firms do not tend to use their technological possibilities to the maximum profitable extent. If they would pursue complete rationality, persons would experience certain disutilities; total utility tends to be maximized by an attitude of less than complete rationality.

Introduction of a new technology, being more profitable than an existing one, means that allocative efficiency would be improved. Entrepreneurs may decide not to adopt the new technology if the increase in allocative efficiency would be more than offset by a decrease in X-efficiency. Leibenstein mentions inter alia the following examples of X-inefficiency (p. 114). First, tastes for various activities may be further from the activity mix that maximizes output under the new technology, compared with the old one. Second, the degree of coordination and factory discipline required may be greater for the new technique than for the old. Third, the existing technique may be carried out fairly efficiently, but in a highly rigid manner, which may be detrimental to the synchronization of activities required under the new technique. Fourth, the system of personnel selection appropriate for the old technique may not be suitable for the new one.

A good example of psychological barriers against a new technology can be found in tele-commuting. Technically, this way of modern home production is possible, and - under certain conditions - it is even more efficient, but the lack of social contacts in tele-commuting - an important aspect of jobs - does not lead to a high acceptance rate of this new technology (see Salomon, 1984).

Considerations such as those mentioned above may give rise to non-adoption, even though the new technique is more profitable than the old one. At a later stage adoption may occur when a further increase of profitability occurs, owing to for example a price reduction of capital goods such as mentioned in section 3.3. The increase in profitability must be large enough to offset the X-inefficiency. Another way of achieving adoption at a later stage would be the improvement of entrepreneurial quality leading to a decrease of X-inefficiency.

3.5. Adoption and Complementary Inputs

Adoption often does not only depend on internal firm conditions, but also on external conditions. To be able to use a new technology in a profitable way, the firm must have access to complementary inputs. A well-known example from agriculture is the introduction of high yielding varieties in developing countries. The adoption of the varieties will be slow when complementary inputs such as water supply (irrigation) and (credit for) fertilizers are not available (see Feder et al., 1982).

Two kinds of complementary inputs can be distinguished: inputs which are supplied on the market, and inputs from social overhead capital.

An important example of the first type is a sufficient quantity of qualified labour to operate a new technology. Also, the supply of services necessary for operating a technology must be mentioned here. For example, in the Netherlands the spatial distribution of computer services is very unequal, the Northern (peripheral) part of the country being strongly underrepresented (see Bouman and Verhoef, 1986). In the situation of excess demand for the new product or technology, one may expect that the spatial pattern of supply of services is led by the development of the spatial pattern of adoption, especially when the services concerned are specific for the new product or technology. This implies a certain advantage for potential adopters in regions where already many adopters are found compared with other regions (agglomeration economies).

Social overhead capital may also play a role as a complementary input with adoption of innovations. Examples are research oriented universities, transport infrastructure (e.g. airports) and telecommunication facilities. Regions with such facilities are candidates for early adoption of innovations. This is a possible point of entry for governments aiming at stimulating innovation adoption.

3.6. Adoption and Institutional Factors

A main institutional factor in innovation adoption is the status of the plant: independent versus branch plant. As indicated by Erickson (1981), the conventional wisdom about branch plants is that their employment stability is rather insecure. In times of recession they are easily closed down. Regions with a high proportion of branch plants will suffer more from recession than other regions. As indicated by Erickson (1981), there is no strong empirical evidence confirming this conventional wisdom.

From the viewpoint of innovation adoption, branch plants appear to perform well compared with independent plants. For the Netherlands, Pellenbarg and Kok (1985) find that branch plants have a higher rate of adoption than independent plants. Similar results are reported for the U.K. by Goddard and Thwaites (1986) and for the F.R.G. by Ewers (1986). For Sweden, Johansson and Karlsson (1986) find that the adoption of process innovation is faster in plants of which the head office is outside the region compared with plants of which the head office is in the region (probably mainly independent plants). A reverse result is obtained for the adoption of product innovations, however.

A plant being part of a larger network has the advantage that information on innovations generated in other regions can be obtained rapidly. Also, financial constraints may be less severe compared with independent plants. Further, Pellenbarg and Kok (1985) report that the educational level of management staff in branch plants tends to be higher than in independent plants.

3.7. Adoption and the Supply Side

The main actor thus far in our discussion of innovation adoption has been the adopter. The supply side has been taken for granted. It only entered in section 3.3. where an exogenous price decrease of the new product was assumed. Supply side bottlenecks may be important (Stoneman, 1986). Thus, the price path of the good produced cannot be set exogenously, but it arises as a result of demand-supply interactions.

Stoneman (1983) presents various models allowing for supply-demand interactions. The diffusion path will be influenced among others by the structure of costs: economies of scale in the production of new technology give rise to decreasing production costs which may lead to decreasing prices. Another important factor is the market structure of the supplying industry, among others the possibility of free entry preventing suppliers from making monopolistic profits. Other potential factors limiting the supply of new products are the lack of venture-capital and lack of qualified labour.

The spatial implications of supply side considerations in the adoption process do not relate to adopters but to the suppliers. This has essentially already been dealt with in the discussion of the product life cycle treated in section 2.

4. Methods for Analyzing Innovation Adoption Data.

Some of the technical problems arising in innovation adoption studies will be discussed by means of an example given in Johansson and Karlsson (1986). Johansson and Karlsson (J & K) study the speed of introduction of information technology systems in Swedish industrial firms. Data are available on a number of relevant features of plants (size, skill of personnel, etc.) as well as on the application data t_k for each plant k.

The first problem met is that information on the date of adoption is censored: many plants have not yet adopted a new good at the end of the time interval covered by the data. In the present case only circa 25 % of the plants had already adopted information technology. Besides, it is possible that some of the plants dropped out of business during the period considered. If the plants which have not yet adopted would be excluded from the analysis, of course a big loss of information would occur. Therefore, J & K try to make a reasonable prediction of the future adoption date of the plants which have not yet adopted (group N).

To make such a prediction, J & K first estimate the time path of adoption on the basis of the data on the plants which have already adopted (group A). Thus, let F (t) be the share of plants which have adopted at or before date t. The values of F (t) are known for t=1 until T, where T is the end of the observation interval. Given these values J & K estimate the parameters a and b of the logistic function (1) by means of least squares. Once the parameters are estimated, one can compute the average time t* it will take before the plants in group N have adopted the new technology. J & K do this by taking t* such that half of the plants of group N will adopt between T and t*, and the other half of group N will adopt after t*.

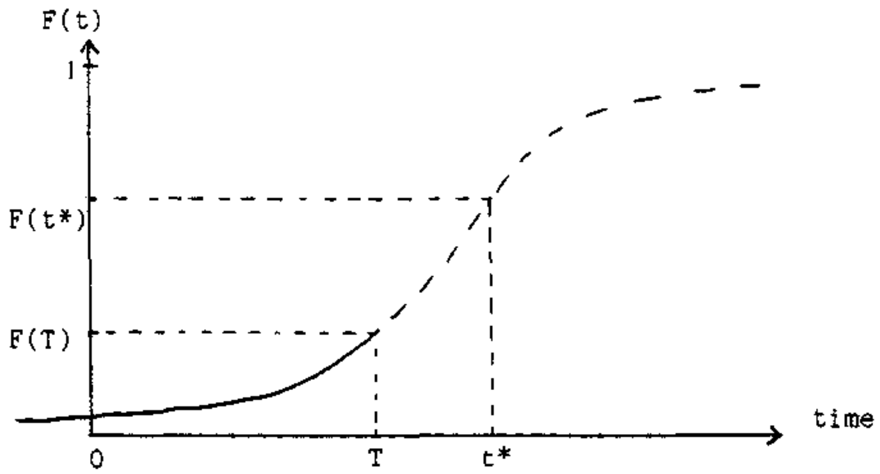

Figure 1. Logistic time path of innovation diffusion.

Thus, t* is fixed such that:

$$F(t^*) = {}^1/_2 + {}^1/_2\ F(T) \qquad (5)$$

which implies that t* is the estimated <u>median</u> time of adoption of plants in group N (see Figure 1).

In the next step essentially the following regression equation is estimated between adoption time t_k and characteristics, $x_{k1},\ldots,x_{kI}$ of plant k:

$$\ln t_k = \alpha + \sum_i \beta_i x_{ik} \qquad (6)$$

where for all plants in group N (non-adopters), t_k is set equal to t^*.

Although the above method is an interesting way of solving the censored data problem, several objections can be raised against it. First, it is questionable that here a logistic diffusion path is assumed. The shape of the diffusion path depends a.o. on the distribution of plant characteristics (see section 3.3), but this information is not used here. The outcome for t^* may be rather sensitive to the specification of the diffusion path, which in its turn will influence the regression results. Second, even if the curve would be logistic, one may not hope to receive a good estimate of the parameters a and b when $F(t)$ is as low as .25. It is rather precarious to predict an adoption path on the basis of only the first quarter of adopters. Third, assigning the same adoption date to every plant in group N is rather crude, and may give rise to big errors in the regression equation.

The background of these problems is the censored character of data: adoption dates are only known until dat T. Fortunately, methods are available to deal with (6) when data are censored. With censored data, equation (6) which is known as the accelerated failure time model, can be estimated by means of maximum likelihood without the need of predicting the adoption date for members of group N (cf. Lawless, 1982). Obviously, the smaller the value of $F(T)$, the more important the above mentioned objections.

We continue now with a second major problem in innovation diffusion studies: usually longitudinal data are not available. One only knows the plant characteristics at time T and the date of adoption. This is a pity, since most plant characteristics vary over time and, what is worse, several characteristics will be influenced by the innovation adoption. For example, scale of production, level of investments, educational level of personnel, are relevant determinants of the decision to adopt, but they may also be influenced by the adoption. Thus, when studying adoption without longitudinal data, causes and consequences are difficult to disentangle.

If one would have longitudinal data, how could they be used to study adoption behaviour? The accelerated failure time model (6) can no longer be used when some of the variables are time dependent. One of the feasible alternatives would be a so-called discrete-time hazard model (see Allison, 1984). Let the hazard rate P(t) be the probability that a plant innovates at date t given that it has not yet innovated:

$$P(t) = [F(t+1) - F(t)]/[1 - F(t)] \qquad (7)$$

Then a discrete-time hazard model can for example be formulated as:

$$\ln [P(t)/(1 - P(t))] = \alpha + \sum_i \beta_i x_{it} \qquad t=1,\ldots,T \quad (8)$$

To estimate the parameters one needs maximum likelihood logit analysis (see Maddala, 1983). For each period t, all plants which have not yet adopted are taken into account, the response variable being 1 in case of adoption and 0 in case of non-adoption. For period t+1 the previous adopters are no longer included in the analysis. By doing so, no problems arise with censored data connected with adopters after time T (see Allison, 1984).

For the estimation it does not matter whether the independent variables are time-dependent or not. One may also formulate α as a time dependent variable, implying that for each period another value could be found. By doing so, one may examine whether in addition to changes in the x_{it} there are time dependent sources of change in the adoption pattern. For other variants of event history methods see Hannan and Tuna (1985).

A third problem in studies of innovation adoption is that a binary approach (adoption=1, non-adoption=0) is often too crude. Firms may have various degrees of adoption which are changing over time. Table 2 shows the four classes which arise when innovation adoption analyses are distinguished according to number of observation (1 versus >1) and way of measurement (binary versus continuous).

		# observations in time: 1	# observations in time: > 1
way of measurement of adoption:	binary	probit, logit, discriminant analysis	event history analysis
	continuous	tobit analysis	tobit analysis for panel data

Table 1. Classification of innovation adaption analyses.

When adoption is measured on a continuous scale, one will usually have observations on some (or many) plants which have not yet adopted at all. Thus, one arrives at a censored dependent variable (the lower limit being zero), which can be studied by means of tobit analysis (see Maddala, 1983). If innovation is formulated as a fraction between 0 and 1, one even arrives at a doubly censored tobit model. For these tobit models, standard estimation programs are available, based on maximum likelihood methods. For the case of tobit models with multiple observations in time (panel data), estimation methods are still in their infancy, however.

Finally, we mention some other problems in the analysis of innovation adoption without further discussing them in more detail. The decision to adopt is usually studied under the assumption that adopters are independent from each other (for example in event history analysis). Interdependencies may be relevant, however, for example in the case of imitation behaviour. Another problem arises when adoption is no longer limited to one type of innovation, so that a mixture of various types is possible, especially when not all elements of the mixture are introduced at the same point in time (see Johansson and Karlsson, 1986).

5. Effects of Technological Development on Regional Labour Markets

The effects of technological change on employment have been a frequently studied research theme. For a survey of theoretical studies on this subject, see Stoneman (1983). Freeman and Soete (1985) review a series of empirical studies from a variety of countries. Both surveys lead to the conclusion that no simple answers can be given concerning the question whether employment will be decreased by technological development. It appears that the net effect depends on a considerable number of parameters which will vary from case to case. We will first discuss some of these parameters in the context of process innovations.

The adoption of a process innovation in a certain sector implies the possibility of an increase in productivity, although Freeman and Soete (1985) remark that in the first stage of adoption the actual productivity increase is much smaller than the potential increase, due to social adaptation processes (cf. section 3.4). In the case of neutral technological development, if output remains the same, employment will fall. There are several compensating effects, however. The improvement of productivity will lead to a price decrease, an increase in wages, an increase in profits, or a combination of these. In the case of a price decrease, output will increase (having a positive impact on employment), depending on the price elasticity of demand for the good concerned. The larger the price elasticity, the larger this compensating effect.

If part of the benefits of technological developments accrue to workers or capital owners, the abovementioned effect will be smaller, but of course another type of indirect effect occurs outside the sector concerned due to an increase of final demand induced by the increase in wages or profits. The size of these effects will depend on income elasticities and labour productivity in the other sectors.

The increase in output of a firm adopting a process innovation can be very large if the other firms in the sector continue to produce with the old technology giving rise to higher production costs. In this case, the employment loss does not materialize in the innovating firm but in the non-innovating firms. If such a process would take place, the degree of monopolism in the market could increase. This would give rise to a reduction in output of the monopolist and hence to a less favourable increase of employment compared to the situation without monopoly creation.

The direction of technological change also plays a role. When the change is labour saving, the direct effect on employment will be a larger decrease so that the probability becomes smaller that compensating effects can outweigh the direct effect. The structure of production is also important. With decreasing returns to scale, indirect effects of technological development will be larger than with increasing returns to scale.

In a multisectoral context, the indirect effects become even larger in number. One has to take into account a technology multiplier effect, since innovation adoption via the introduction of new capital goods leads to employment effects in the capital goods producing sector.

Employment efects of product innovations have been studied by Katsoulacos (1984) in an analytical model. In this model, the introduction of a new product leads to a higher utility people derive from consumption, giving rise to an increase of labour supply and employment. This effect is greater, the smaller the degree of substitutability between the new product and the old products. The effect is zero with infinite substitutability, implying that the new product actually does not add anything really new to the existing set of products. The introduction of the new product will lead to a decrease in the demand of (some of the) other products. Katsoulacos shows that when labour productivity is the same for all products, the net employment effect of the product innovation will be positive. In another version of the model, Katsoulacos also studies the influence of market structure on employment effects of product innovations. He finds that the employment generating effects of a product innovation is enhanced if it is realized by the entry of new firms on the market as opposed to existing firms.

Freeman and Soete (1985) note, in their review of a number of empirical studies on the employment impacts of new technologies for various countries, that no common view is obtained. A tendency is observed that in countries which are strong in information technology industries (such as Japan), the employment generating aspects of new technology come to the fore, while in other countries the labour replacing effects are emphasized. Non-adoption of new technology in sectors operating on a competitive world-market will probably lead to even larger job losses, since production costs remain too high according to world standards. The job losses due to non-adoption appear difficult to measure in empirical studies (see for further studies on the information technology also Blackburn et al., 1985, and Jussawalla and Ebenfield, 1984).

Two approaches are usually followed to study the employment effects of a new technology. First, the macro approach tries to capture the effects of technological change by means of macro economic models, usually taking into account the input-output structure of the economy. The problem with the macro approach is that it is difficult to find an entry for using detailed sectoral information. Second, the micro approach is used in order to study employment effects in a narrowly defined industry in combination with its relevant suppliers and customers. The problem with this approach is that some of the compensating effects mentioned above are very difficult to take into account. Clearly, the development of methods to link the two approaches will help to obtain more reliable impact assessments of technological change.

In the above discussion of the employment effects of technological change, the labour market is taken as homogeneous. In reality of course submarkets exist according to space, skill level, etc. Thus, even when the results lead one to the conclusion that on average job creation and job losses due to technological change tend to be in balance, this will certainly not hold true for particular submarkets, due to dual and segmented labour markets.

The product life-cycle theory may help one to assess these effects (see Johansson and Karlsson, 1986, and section 2). An important implication of the product life cycle theory is that if there is no continuous introduction of new products to fill the gaps caused by the products which have already followed part of the cycle, major instabilities will arise on the labour market. In each cycle, the relative demand for high skilled and low skilled workers is different, requiring substantial flexibility of labour supply to achieve equilibrium. A similar implication holds true for spatial disequilibrium on the labour market. The product cycle will subsequently lead to rural-urban migration, suburbanization and desurbanization tendencies.

The urban-rural manufacturing shift, observed in the countries of the EEC, is consistent with the product life cycle theory. Since the

1970s the highly urbanized regions have lost a large share of manufacturing employment. In rural regions on the other hand there was almost no loss of employment, which implies that a considerable redistribution of manufacturing employment has taken place (see Ewers, 1986). In terms of life cycle theory this is what may be expected when most of the products enter the maturity phase. A new wave of new products would give rise to a reverse trend, however. In that case, the relatively good performance of rural manufacturing is only a temporary phenomenon.

The product life cycle theory suggests that in the early phase of the introduction of information technology, the metropolitan areas will mainly experience benefits. It is here that most of the R&D activities take place and major parts of high technology sectors are also located here (see section 2). On the other hand, in peripheral areas job losses will tend to outweigh job creation in this stage of the product cycle (see also Goddard and Thwaites, 1986).

One may wonder whether it is wise for a government to consider the closure of a region (or the whole country) to avoid the introduction of a certain new technology which may be expected to give rise to large job losses, the positive employment effects being realized in other regions or countries. The answer depends to some extent on the spatial scope of the market concerned.

In the case of goods for which there is an international market, a closure policy for new technology to produce these goods can only be effective when it is accompanied by a closure for the good itself in the form of import tariffs or a quota system. Exports will be very difficult to realize in this case. This policy is used for example by governments in some developing countries with an abundant labour force, which out of concern for employment in labour intensive industries place limitations on the installment of new machninery. For example, cigarette firms may only produce a limited share of output with machines, the rest must be produced manually. A larger share of output produced with machines would lead to big job losses and probably only small positive compensating effects in the countries concerned: the machinery has to be imported. Further, the reorientation of consumption induced by a price decrease of cigarettes will most probably not lead to the creation of a sufficient number of new jobs, given the very high labour intensity in manual cigarette production. Yet, in the long run this closure policy is unattractive since it creates for the country concerned more and more old fashioned production technology. At best one may think of a closure policy in terms of gradually relaxing limits on the introduction of a new technology, so that by controlling the diffusion speed sudden shocks in employment are avoided. At the interregional level this policy is difficult to realize, since import tariffs cannot easily be introduced for interregional trade within a country.

In case of a good whose market is more limited in space (e.g., most services), some of the above objections against closure are no longer relevant. However, effective inspection will often be difficult to realize. Besides, a (selective) technology closure policy may deprive regions of the possibility to keep up with external developments, so that its future competitiveness will be made worse. This argument also holds true for a technology-closure in the sector which is most easy to control: the government sector itself. Apart from the fact that regional governments do not seem to be early adopters of innovations, a technology closure in the public sector of certain regions may have detrimental effects on the quality of public services in these regions.

We conclude that there are several serious objections against the idea of a selective technology of regions as introduced by Stöhr and Tödtling (1977). There must be better policies to help vulnerable regions to stand the challenge of technological development. Examples may be found in the innovative potential of small and medium sized business sectors.

6. Conclusion

In this paper, the two-sided relationship between technological development and regional labour markets has been discussed. It appears that the qualification of regional labour supply are an important determinant of R&D and the speed of innovation adoption, influencing the degree of regional competitiveness. On the other hand, technological development has far reaching consequences for the size of labour demand and its composition according to skills and regions.

Special attention has been paid to the (spatial) diffusion of innovations. Due to a lack of longitudinal data, it is often very difficult to distinguish between causes and consequences of innovation adoption.

Governments have various policy handles to influence regional labour markets in view of technological change. The provision of educational facilities will influence the location of R&D activities in the private sector, and also the speed of adoption of innovations in various regions. Investment subsidies may speed up the rate of innovation adoption in peripheral areas. Besides, government as an important customer of high technology (e.g. defense) can give priority to suppliers from certain regions. When in certain regions the adoption of innovations is hampered by a lack of complementary inputs, governments may aim at removing such bottlenecks. As discussed in section 4, government intervention by selective spatial closure to prevent regions from adopting certain labour saving technologies will be difficult to implement and may have adverse effects. It is advisable to consider other - more positive - means to take care of employment goals in weak regions (e.g., by stimulating small and medium size industrial and sectors).

References

Abler, R., J.S. Adams and P. Gould, Spatial Organization, Prentice Hall, London, 1972.

Allison, P.D., Event History Analysis, Sage Publ., London, 1984.

Blackburn, P., R. Coombs and K. Green, Technology, Economic Growth and the Labour Process, MacMillan, London, 1985.

Bouman, H. and B. Verhoef, High-Technology and Employment: Some Information on The Netherlands, in: P. Nijkamp (ed.), 1986 (forthcoming).

Camagni, R.P., Innovation and the Urban Life-Cycle: Production, Location and Income Distribution Aspects, in: P. Nijkamp (ed.), 1986 (forthcoming).

David, P.A., A Contribution to the Theory of Diffusion, Stanford Center for Research in Economic Growth, Memorandum no. 71, Stanford University, Stanford, 1969.

Erickson, R.A., Corporations, Branch Plants and Employment Stability in Nonmetropolitan Areas, in: J. Rees, G.J.D. Hewings and H.A. Stafford (eds.), Industrial Location and Regional Systems, Croom Helm, London, 1981, pp. 135-154.

Ewers, H.-J., Spatial Dimensions of Technological Developments and Employment Effects, in: P. Nijkamp (ed.), 1986 (forthcoming).

Feder, G., R.E. Just and D. Zilberman, Adoption of Agricultural Innovations in Developing Countries, World Bank Staff Working Paper 542, Washington, 1982.

Freeman, C., the Economics of Industrial Innovation, Penguin, Harmondsworth, 1974.

Freeman, Ch. (ed.), Design, Innovation and Long Cycles in Economic Development, Design Research Publ., Royal College of Art, London, 1984.

Freeman, C. and L. Soete, Information Technology and Employment: An Assessment, Science Policy Research Unit, University of Sussex, 1985.

Goddard, J.B. and A.T. Thwaites, New Technology and Regional Development Policy, in: P. Nijkamp (ed.), 1986 (forthcoming).

Hagerstrand, T., Diffusion of Innovations, University of Chicago Press, Chicago, 1968.

Hannan, M. and N. Tuna, Dynamic Analysis of Qualitative Variables, in: Measuring the Unmeasurable, (P. Nijkamp, H. Leitner and N. Wrigley, eds.) Martinus Nijhoff, Dordrecht, 1985, pp. 629-681.

Hoogteijling, E., J.W. Gunning and P. Nijkamp, Spatial Dimensions of Innovation and Employment: Some Dutch Results, in: P. Nijkamp (ed.), 1986 (forthcoming).

Johansson, B. and C. Karlsson, Industrial Applications of Information Technology: Speed of Introduction and Labour Force Competence in: P. Nijkamp (ed.), 1986 (forthcoming).

Johannson, B. and C. Karlsson, Processes of Industrial Change: Scale, Location and Type of Job, 1986 (this volume).

Jussawalla, M. and H. Ekenfield (eds.), Communication and Information Economics, North-Holland Publ. Co., Amsterdam, 1984.

Kalbfleisch, J.D., and R.L. Prentice, The Statistical Analysis of Failure Time Data, Wiley, New York, 1980.

Katsoulacos, Y., Product Innovation and Employment, European Economic Review, vol. 26, 1984, pp. 83-108.

Lancaster, K., Consumer Demand, A New Approach, Columbia University Press, New York, 1971.

Lawless, J.F., Statistical Models and Methods for Lifetime Data, Wiley, New York, 1982.

Leibenstein, H., General X-Efficiency Theory and Economic Development Oxford University Press, New York, 1978.

Maddala, G.S., Limited Dependent and Qualitative Variables in Econometrics, Cambridge University Press, Cambridge, 1983.

Malecki, E.J., Recent Trends in the Location of Industrial Research and Development: Regional Development Implications for the United States, in: J. Rees, G.J.D. Hewings and H.A. Stafford (eds.), Industrial Location and Regional Systems, Croom Helm, London, 1981, pp. 217-238.

Mouwen, A. and P. Nijkamp, Information Centers as a Tool in Regional Development Policies, Information and Urban Growth (J. Brotchie, P. Hall and P. Newton, eds.), Croom Helm, London, 1986 (forthcoming).

Nijkamp, P. (ed.), Technological Change, Employment and Spatial Dynamics, Springer, Berlin, 1986 (forthcoming).

Pellenbarg, P.H. and J.A.A.M. Kok, Small and Medium-Sized Innovative firms in the Netherlands' Urban and Rural Regions, TESG, vol. 76, 1985, pp. 242-252.

Schumpeter, J.A., The Theory of Economic Development, Harvard University Press, Cambridge, MA, 1934.

Stöhr, W. and F. Tödtling, Spatial Equity - Some Anti-thesis to Current Regional Development Doctrine, Papers of the Regional Science Association, vol. 38, 1977, pp. 33-53.

Stoneman, P., <u>The Economic Analysis of Technological Development</u>, Oxford University Press, Oxford, 1983.

Stoneman, P.L., Technological Diffusion: The Viewpoint of Economic theory, Conference on Innovation Diffusion, Venice, March 1986.

Van den Berg, L., R. Drewet, L.H. Klaassen, A. Rossi and C.H.T. Vijverberg, <u>Urban Europe, A Study of Growth and Decline</u>, Pergamom Press, Oxford, 1981.