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Localized Technological Progress and Industry Strucutre

An Empirical Approach

von

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1« Introduction

Modem Innovation Theory suggests the concept of localized technological progress which criticizes the traditional neoclassical concept of the sources and effects of technological change, the firm's choice of technique and as a consequence the concept of the production function. In a short-cut, localized technological progress refers to the fact that new technological opportunities are generated and explored by firms under different, firm specific conditions which leads to intra-sectoral heterogeneity in the production techniques applied and the technical efficiency performed. Neoclassical formulations just contrary further the view that firms adjust in a rather similar fashion to some externally given and growing technological opportunities represented by a known parametric isoquant which in equilibrium implies technical and performance homogeneity.

From the empirical point of view the neoclassical approach applies well elaborated statistical procedures to estimate sectoral parametric production functions. Those methods principally rely on the assumptions of equilibrium and firm homogeneity; industry structures nevertheless to be observed are then interpreted mainly as a transitory phenomenon or can be traced back to some market breakdowns. A switch of the theoretical basis towards modem innovation theory does necessarily imply that for the detection of industry structures the neoclassical tools are not appropriate any more. A smooth production function applied by all firms of a sector does not exist.

Based on this, our paper presents a non-parametric method, Data Envelopment Analysis (DEA), suitable to detect industry structures based explicitely on the technical heterogeneity of firms and therefore of the respective production functions. With this method we show how vertical and horizontal intra-sectoral structures can be determined and how one can track the development of those structures over time. Parts of our presentation rely on our previous work such as Bemard/Cantner/Westermann (1995), Cantner/Hanusch/Westermann (1996), or Bemard/Cantner/Hanusch/Westermann (1994). In addition we provide (a) an improved procedure to detect "dominant techniques" and (b) a modified DEA-model which helps to resolve the problem that in the standard version of DEA all best-practice firms (techniques) are considered as equally performing. Those new aspects help to get an even better account of industrial dynamics.

Section 2 delivers theoretical arguments and methodological requirements for an empirical investigation of industry structures which are caused by localized technological changes. Neoclassical innovation theory and the theory of localized technological change are contrasted here. Section 3 introduces DEA. By way of illustration section 4 provides an application of this method to the sectors machinery, chemistry and electronics of the German economy and shows how industrial structures and dynamics can be detected and tracked. Final remarks and an outlook conlude in section 5.

2. Theoretical Foundations and Methodological Requirements

Investigations into the dynamics of industries are necessarily concerned with industrial structures and their change over time. Within this context our analysis focuses on technique and performance structures and on how those structures are affected by technological progress. In order to make such concepts operational we have to define what we mean with a production technique and with technical performance. Here we stick to economic (instead of technical) definitions where a certain technique is defined by the ratio of factor inputs used; the respective technical efficiency level achieved is given by the amount of factor inputs used in order to produce one unit of output. With these two definitions in mind we discuss in this chapter quite briefly two different theoretical approaches towards industrial structures and change, the neoclassical theory of production and technological change on the one hand and modem innovation theory on the other. And here, we restrict our discussion on the interrelationship between the generation and the choice of techniques.

Conventional neoclassical production theory claims that the choice of technique and the generation of the set of accessable techniques are quite distinct activities. In its standard version a rationally optimizing firm is able to choose among an infinite number of different, arbitrarily close techniques - represented by an smooth isoquant connecting all technically efficient combinations of substitutable inputs to produce one unit of output. On this basis a firm's choice of a production technique is - as the result of profit maximization or cost minimization - principally governed by relative factor prices where an optimal technical adjustment is always possible, costless, and with technical and allocative efficiency necessarily to be obtained. Considering a specific economic sector in equilibrium this result holds for all firms which implies that in fact the same unique technique - one unique point on an isoquant - will be choosen.

Changes in the technique over time are caused by substitution and by technological progress. The former refers to the effects of a change in relative factor prices leading to a movement along the isoquant until a new equilibrium is reached. Technological change, on the other hand, is considered as exogenously given and generic, affecting all techniques equally. For any such technological change taking place, the isoquant shifts inward and firms adjust their technique in accordance to the respective factor saving until the new equilibrium position has been reached.

For any empirical research on the sectoral level it is not at all surprising that those - in fact structureless - equilibrium states will not be detected. A "natural" way to explain any deviations from the idealized, theoretical solution is

(1) to argue that the system is on its adjustment path to a (new) equilibrium - with any adjustment requiring time to work through;

(2) to point to a not well functioning (factor) market mechanism, institutional rigidities, separated markets, and other breakdowns which prevent the market forces to work in a way theory predicts.[1]

Traditional empirical methods, in fact, rely on those two explanations. With respect to (1), applying well elaborated statistical procedures neoclassical empirical research attempts to extract out of the noisy data significant estimates for the average-practice or representative firm's production function - on the average the neoclassical position is supposed to hold. Deviations from this and therefore industry structures are considered as accidental and only temporary. Concerning (2), it is accepted that firm performances differ so that the estimation of a sectoral best-practice production function is appropriate. This smooth technology frontier serves as a yardstick for all firms where technical as well as allocative inefficiencies are the rule not the exception: firm differences are an expected result which have to be analyized further.[2] For both, (1) and (2), a crucial asssumption is that all firms apply the parametrically same production function. This simplification is even preserved when the effects of technological change are considered: The detection of those effects is provided for by introducing a time trend variable affecting the level of the respective - average or best-practice - production function - assuming that technological change is exogenous and affects all firms equally. Consequently, structural dynamics caused by technological progress is reduced to some on-the average-changes (either of the average-practice or the best-practice frontier).

Despite the theoretical and methodological merits of this neoclassical story what it lacks is a deeper consideration of the source and origin of firms production techniques. This lack leads us directly to modem innovation theory which critizeses the neoclassical separation between the choice and the generation of techniques. The starting point is that the neoclassical perception of an exogenous and generic technological progress gets challenged by the concept of localized technological change which argues

(1) that a high proportion of technological innovations is generated on the firm level, i.e. technological progress is endogenous,

(2) that those advances are dependent on the (past and actual) activities of the firm and therefore on the technique already chosen, i.e. technological progress is path-dependent, and

(3) that the "fruits" of those activities spill over to other firms only by degree, i.e. know-how is partly private and tacit.

Thus, technological change which is considered as local implies that not all techniques on an isoquant are affected so that either a single technique (strong localized progress as in Atkinson/Stiglitz (1969), Freeman/Soete (1987)) or due to spillover effects a certain part of an isoquant shifts inward (weak localized progress as in Verspagen (1990)). Consequently, the neoclassical clear-cut separation of the generation and choice of techniques disappears. Both aspects are rather interrelated what can be explained as follows:

The first argument is entirely technological: In most cases the beneficial effects of technological progress do not accrue to all possible or practiced techniques because they are dependent on local learning effects (Atkinson/Stiglitz (1969), Stiglitz (1987)), technical interrelatedness (David (1975)), absorptive capacities (Cohen/Levinthal (1989)), and bounded rational search and R&D activities (Nelson/Winter (1982)). Consequently, independent of the sources of technological progress and by whatever reason and motivations firms persue technological progress, its localized and endogenous nature provides the new technique to be comparably close to the old one.

This effect applies even the more when the cumulative nature of technological advances is taken into account (Dosi 1988).

The second argument is economical: Even when changing relative factor prices suggest to apply another technique in order to reduce costs, the switching is not as easy and costless as the neoclassical theory assumes. Switching costs (Freeman/Soete (1987), David (1975)) due to the installation and deinstallation of machinery, to search activities, to foregone opportunities and knowhow in the old technique, etc. may be considerable and constrain or even prevent the degree of substitution taking place. Allocative inefficiencies will then not (entirely) be eliminated by substitution but (also) by innovation (Antonelli (1994a), (1994b)).

The third argument is a consequence of the first and the second: With localized technological progress the substitution possibilities between factors along an isoquant will be reduced (Atkinson/Stiglitz (1969)). This implies that certain techniques are optimal for a certain range of relative factor prices with allocative efficiency to prevail.

Finally, different capabilities to persue technological progress and to change techniques lead to differences in the technique choosen and in the technical performance.

Based on this concept, for an industry structure and its development we can put forward the following:

(1) Differences in the choice of technique among firms are not an only transitory phenomenon but firm heterogeneity is a consequence of localized technological advances. Such heterogeneity refers to the kind of production technique applied, i.e. horizontal heterogeneity, and to the technical efficiency achieved herewith, i.e. vertical heterogeneity.

(2) The firm specificity and cumulativeness of technological advances suggests that there is some degree of stability in the industry structure with different equally efficient best-practice firms staying at the technology frontier over time.

(3) Allowing for technological knowhow to spill over partially to other firms one might expect to find groups of firms which apply quite similar techniques albeit with different technical efficiency.

(4) The structural dynamics and changes within a sector are generated by the interplay of firm specific technological advances (dominating rather in the short-run), spillover effects and some (general) economic influences such as relative factor price changes (dominating rather in the long-run).

Finally, what do these theoretical propositions imply for empirical analyses? The technical heterogeneity of firms suggests that they do not all produce with the (parametrically) same production function. According to at least in the short-run limited substitution possibilities those functions could be approximated by Leontief-type functions although this assumption is not necessary.[3] The neoclassical concept of a smooth isoquant is not applicable for an industry structure as defined above. Isoquants are rather to be considered as a frontier consisting of several linear parts connecting a number of realized, best-practice techniques, the "accessable process frontier" (David (1975, pp.62)). Consequently, the determination of a common sectoral and parametric best-practice production function by the well-known methods of frontier-analyses is not applicable. Structural dynamics and change cannot be taken as an on-the-average phenomenon. It is rather to be considered as a process that affects only parts of the accessable process frontier and therefore cannot be detected with usual estimation techniques.

With these theoretical and methodological requirements in mind we will deviate in our empirical approach from usual econometric techniques and suggest a method which is suitable for detecting industry structures and dynamics caused by localized technological advances.

3. The Analytical Model

The analytical approach we apply is non-parametric, principally based on a linear programming procedure and known as the ***Data Envelopment Analysis*** (DEA). This well-known method goes back to the seminal work of Charnes/Cooper/Rhodes (1978) and Banker/Charnes/Cooper (1984). On this basis it is possible to obtain an index for relative technical (in)-efficiency for each firm of the sample. The choice of a non-parametric approach helps to take account of heterogeneity by allowing for several parametrically different production functions.

3.1 Basic Model

Principally DEA relies on index numbers for productivity similar to the ones used in traditional productivity analysis. For each firm j ($j=1,\ldots,n$) a productivity index h_j is given by:

$$h_j = \frac{u^T Y_j}{v^T X_j} \tag{1}$$

Here Y_j is a s-vector of outputs ($r=1,\ldots,s$) and X_j a m-vector of inputs ($i=1,\ldots,m$) of firm j. s-vector u and m-vector v contain the aggregation weights u_r and v_i respectively.

The h_j in (1) is nothing else than an index for *total factor productivity*. The respective aggregation functions (for inputs and outputs respectively) are of a linear arithmetic type as also employed in the well-known Kendrick-Ott productivity index.[4] There, however, by special assumptions the aggregations weights, u_r and v_i, are given exogenously.

The DEA-method does not rely on such assumptions, especially it is not assumed that all firms of the sample have a common identical production function. The specific aggregation weights are determined endogenously and can differ from firm to firm.

They are the solution of a specific optimization problem (as discussed below), and therefore they are dependent on the empirical data of our sample.

The basic principle of DEA is to determine the indices h_j in such a way that they can be interpreted as efficiency parameters. The (relatively) most efficient firms of a sample should be characterized by a h of 1, all less efficient firms by a h of less than 1. The following constrained maximization problem is used to determine such a h-value for a specific firm l, $l \in \{1,\dots,n\}$, out of the sample:

$$\max\ h_l = \frac{u^T Y_l}{v^T X_l}$$

$$s.t.: \frac{u^T Y_j}{v^T X_j} \leq 1; \quad j=1,\dots,n; \qquad (2)$$

$$u, v > 0.$$

Problem (2) determines h_l of firm l subject to the constraint that the h_j of all firms of the sample are equal or less to 1. The constraints provide that h is indexed on $(0,1]$. Moreover the elements of u and v have to be strictly positive. This requirement is to be interpreted that for all inputs used and outputs there exists a positive value.[5]

Since we employ linear arithmetic aggregation functions for inputs and outputs, (2) is to be rendered as a problem of linear fractional programming.[6] To solve such optimizations, there exist a number of methods where the best known is the one by Charnes and Cooper (1962). They suggest to transform (2) into a normal linear programm which then can be solved using the well-known simplex algorithm. Performing this step and transforming the resulting primal to its dual problem one arrives at the well-known Charnes/Cooper/Rhodes[7] envelopment form of DEA:

$$
\begin{aligned}
&\min\ \theta_l - \epsilon e^T s_l^+ - \epsilon e^T s_l^- \\
&s.t.: \\
&\qquad Y\lambda_l - s_l^- = Y_l \\
&\theta_l X_l - X\lambda_l - s_l^+ = 0 \\
&\lambda_l, s_l^+, s_l^- \geq 0
\end{aligned}
\tag{3}
$$

Y_l and X_l are the r- and s-vectors of outputs and inputs respectively of firm l, Y and X are the $s \times n$-matrix of outputs and $m \times n$-matrix of inputs of all firms of the sample. The parameter θ_l to be minimized accounts for efficiency, the j-vector λ_l provides information about reference sets, (s_l^+) and (s_l^-) are the excess inputs and output slacks respectively, vector e^T contains only elements 1[8], and ϵ is the positive socalled Non-Archimedian constant[9]. The interpretation and the purpose of these variables and parameters will be discussed in the following.

3.2 Inefficiency Measures or Vertical Heterogeneity

The parameter θ_l to be minimized in (3) states to which percentage level the inputs of firm l can be reduced proportionally in order to become efficient. With $\theta_l=1$ the respective firm belongs to the efficient firms on the frontier, otherwise the firm is inefficient. Thus, the measures θ_l, $l=1,\ldots,$n, give an account of the vertical heterogeneity where the benchmark of comparison is the best-practice technolology frontier. Below best-practice firms are usually compared with a linear combination of a subset of the frontier firms.[10] θ_l provides information about the relative (vertical) position of firm l's technique towards a linear combination of best-practice techniques.

As is known, a proportional reduction of inputs (as given by θ_l) does not necessarily lead to efficiency in the Pareto-Koopmanns sense. In order to correct for this the remaining excess inputs (s_l^+) and output slacks (s_l^-) are taken into account in the objective function.

On this basis, for efficiency analyses additional to θ one has to take into account remaining output slacks or excess inputs. Only then a clear-cut selection of efficient and inefficient firms is possible. For simple qualitative statements this procedure is sufficient.

For a quantitative analysis, however, it would be helpful to combine the proportional reduction θ_l, s_l^+ and s_l^- into a single measure. This is done by a method suggested by Ali/Lerme (1990):

As is known from index numbers for total factor productivity the input factors have to be aggregated in a single number. Applying DEA, the respective weights are given by the marginal productivities of the input factors of the reference firm. These marginal productivities are the solution of the primal program of (3). Using the marginal productivities of the respective reference firms (determined by the non-zero elements of the vector λ_l) one can weight the inputs on the one hand and the s_l^+ and s_l^- of firm l on the other hand. The ratio between both delivers the percentage of the additional inefficiency. Subtracting this measure from θ_l delivers an adjusted aggregate measure of inefficiency ι_l. For our empirical analysis below we rely solely on ι_l.

3.3 Detecting Technology Fields or Horizontal Heterogeneity

The discussion above has shown that the θ-measures help to detect vertical heterogeneous performances among firms by comparing the respective per unit output factor use. In addition to this structure the DEA-method allows also to group firms which apply quite similar techniques, i.e. to detect a horizontal structures.

For this purpose we refer to the j-vector λ_l which contains the weights of all (efficient) firms which serve as reference for firm l. For a best-practice firm l (with $\theta_l=1$), we obtain 1 for the lth element of λ_l and 0 for all other elements. For below best-practice firms the lth element of λ_l is 0 and some other elements show positive values.

Consequently, λ_l provides information about who are firm l's reference firms (peer group).

Concerning the weights of the reference firms to l the following holds: the higher the weight of firm p in λ_l the closer is the technique of l to the one of p. Thus, the weight of the λ-vector can be used to assign below best-practice firms to the closest best-practice firm on the frontier.

3.4 Comparing the Best

In empirical applications the DEA delivers quite regularily more than one best-practice firm, all given a ι_l of 1. This evaluation relies on the concept of Pareto-Koopmanns efficiency and the respective firms are evaluated as equally performing. However, it is still possible to find a measure that allows to compare even those firms (see Andersen/Petersen (1989)). For this purpose one might ask to what extend those best-practice firms may increase their respective inputs proportionally in order to stay just on the frontier. The higher this percentage number the larger is the gap between an investigated firm and the "competitors".

Such information can easily be inferred from a slightly modified version of program (3):

$$\begin{aligned}
&\min\ \theta_l^0 - \epsilon e^T s_l^+ - \epsilon e^T s_l^- \\
&s.t.: \\
&\qquad Y\lambda_l^0 - s_l^- = Y_l \\
&\theta_l^0 X_l - X\lambda_l^0 - s_l^+ = 0 \\
&\lambda_l^0, s_l^+, s_l^- \geq 0
\end{aligned} \tag{4}$$

The modification refers to the vector λ_l^0 which now contains the weights of all firms except the analyzed firm l and to θ_l^0. Why this? A firm which is evaluated as efficient by program (3) is its own reference firm with the lth element of λ_l equal to 1. Preventing this solution by defining a vector λ_l^o provides that firm l will be related now to firms which are with (3) only as good or worse than l. Consequently the inefficiency measure θ_l^o now will be larger than 1 and states the proportional percentage increase in inputs in order to stay just best-practice.

4. Empirical Investigation

4.1 Description of the Data

We investigate the vertical and horizontal structures of three main sectors in the German manufacturing industry: Chemicals (incl. pharmaceuticals), electronics and machinery.

For our analysis we construct three sector specific firm samples that are time consistent in the sense that we have neither entries nor exits of firms over the whole period under investigation (1981 to 1991). Firms that enter or leave the sector during this time are not considered. Additionally, all firms within the three samples are of the legal form "shareholders´ company". Thus, for our investigation we analyze 33 chemical, 27 electronics and 71 machinery firms for 11 years each.

The respective data are drawn from the annual reports of the firms and then processed in order to compute the efficiency score ι together with some additional DEA measures. Therefore we define some suitable variables for one output and two inputs.[11] As output measure we use "value added" deflated by a composed price index for German investment goods. On the input side we distinguish between "capital" and "labour": "Capital" is represented by the balance sheet position "fixed assets" (net value at the beginning of the year). Since we have no information about the vintage structure of capital this measure is not price-deflated, but corrected by an industry specific index for the annually deviation in capacity use. For "labour" we compute the effective worker hours per year by multiplying the number of workers of a firm by an industry specific index of effective worker hours.

We are certainly aware of the fact that in order to compute a measure for technical efficiency we should have used pure technical variables for the inputs or the output. In some cases such data are not available, in others the variables are too heterogeneous to be measured technically. Thus, we have to replace or aggregate the real data by economically weighted values.

4.2 Efficiency: Structuring Vertically

In accordance to the theory of localized technological change a sectoral accessable process frontier is represented by those firms which perform best-practice. Our first step attempts to detect this frontier and to investigate the structure and dynamics of firm performances with respect to this frontier. For this purpose we use model (3), determine ι-values for all firms and divide the respective sample in a set of best-practice firms with $\iota = 1.0$ and a set of below best-practice or inefficient companies with $\iota < 1.0$. This vertical structure of a sector will be analyzed statically where we focus on the set of best-practice firms and investigate the stability of this set over time. A dynamic analysis is then concerned with the development of the relation between best-practice and inefficient companies.

4.2.1 A Static Analysis of Firm Performance

For our static analysis we compute ι-values as results of a year-by-year consideration. Thus, an "technical" efficiency frontier is determined for each year which allows to evaluate the inefficiencies of the "non-frontier" firms. In this early stage of the investigation we simply focus on the yearly technical performance of the firms, still neglecting any technological static or dynamic feature. A ι-value calculated according to this procedure shall be called a "static" ι.

Tables 1a, 1b and 1c show the DEA-efficient firms in a year-by-year analysis and the periods they stay on the frontier for the three sectors respectively. In the machinery sector there no firm is continuously member of the efficient set while for the electronics industry company #369 seems to be dominating permanently and #581 leads in the chemical sector at least for the first nine years. Other firms improve their efficiency up to a ι-value of 1.0 during the period under consideration (e.g #499 in electronics or #406 in chemicals). Firms like #489 in machinery or #709 in chemicals loose their leading position after some years while others (e.g. #886 in electronics) appear only for a short period on the frontier. The number of efficient firms is varying from 1 to 3 (1 to 4; 1 to 5) firms per year for the chemicals (electronics; machinery) sector with no significant de- or increasing tendency for chemicals or machinery whereas the electronics sector clearly shows a maximum in the last three years.

From this result we learn that the structure and development of the best-practice frontier is dominated by a single firm in the chemicals and electronics sector while in machinery a discharge in leadership from time to time seems to be the rule. Despite this stability at least in two of the three sectors some of the facets on the frontier vanish and others appear from period to period in all analyzed industries.

Table 1a: Best-Practice Firms Chemicals

firm-id \ year	81	82	83	84	85	86	87	88	89	90	91
271			X								
406										X	X
467										X	
581	X	X	X	X	X	X	X	X	X		
709	X	X	X			X				X	

Table 1b: Best-Practice Firms Electronics

firm-id \ year	81	82	83	84	85	86	87	88	89	90	91
53											X
369	X	X	X	X	X	X	X	X	X	X	X
499									X	X	X
505									X		
509									X		
886							X				

Table 1c: Best-Practice Firms Machinery

firm-id \ year	81	82	83	84	85	86	87	88	89	90	91
174	X										
201			X		X		X	X			
211							X		X		
272	X										
332						X	X	X	X		
371					X		X	X	X		
437						X					
463										X	X
480			X		X	X					X
482							X	X			
489	X	X	X	X	X					X	
515											X
537											X
768								X			

4.2.2 A Dynamic Perspective

In the next step we want to learn something about the dynamics of the technologically determined structure. Here we are interested in the relative "speed" (a) of the movement of the efficiency frontier and (b) of the non-efficient firms (adopting new technologies or improving old ones). Figures 1a-c show the average "static" ι-value of the inefficient group (NEFFSTAT) together with the average "static" ι-value of the efficient firms (EFFSTAT) (which, of course, has to be 1.0 by definition) for the three sectors. To obtain a measure of the movement of the frontier we compute another average ι-value for the efficient sub-sample (EFFDYN) as a compared towards the "all-time-best-practice" frontier. This kind of efficiency measure shall be called a "dynamic" ι.

The following observations seem to be most important. First of all, the efficiency of the "static" best-practice frontier (EFFDYN) shows decreasing as well as increasing tendencies over time. This result furthers the perception that technological progress is not a continuous process. Moreover, since our measures for factor inputs include the firm efforts in R&D, a decreasing efficiency implies that those activities are not successful (at least) at once; a lateron increasing efficiency could consequently be interpreted as innovative success.

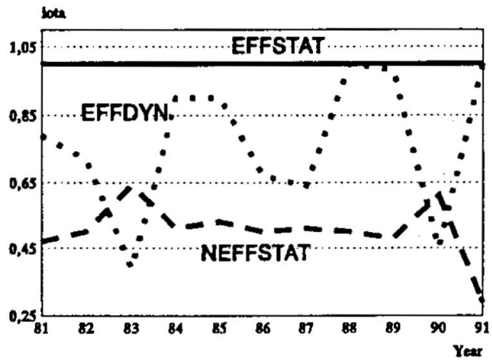

Fig. 1a: Chemistry (source: own calculations)

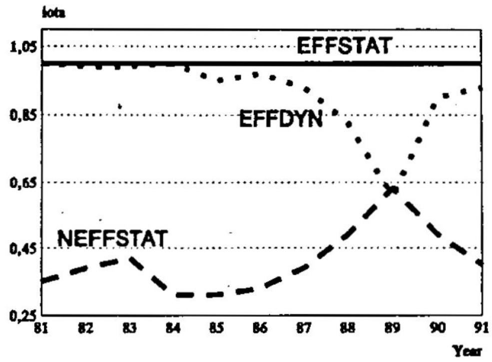

Fig. 1b: Electronics (source: own calculations)

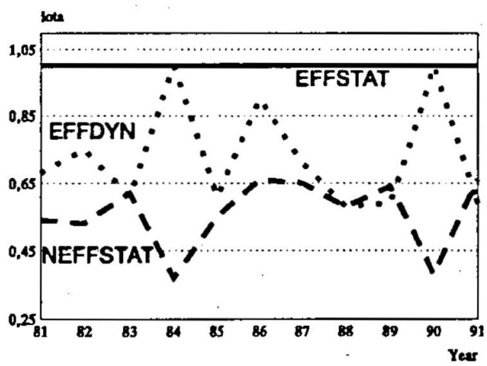

Fig. 1c: Machinery (source: own calculations)

Besides this, comparing the development of NEFFSTAT and EFFDYN allows to draw conclusions about possible catch-up or falling-behind processes. First, whenever almost mirror-inverted curves NEFFSTAT and EFFDYN appear, such as in the electronics sector, this indicates that the efficiency losses or gains (which are relative measures) of the inefficient subsample are mainly the result of a frontier-shift. Catch-up/falling-behind processes play a minor role. Second, a nearly unchanged average NEFFSTAT demonstrates that the inefficient companies could neither close the gap towards the frontier firms nor were the technology leaders able to enlarge their lead. This applies for the chemical industry in the period 1984-89 where the inefficient firms implicitely follow the wave-like EFFDYN movement of the best-practice frontier. Third, catch-up (falling-behind) processes are indicated by a parallel upward (downward) movement of NEFFSTAT and EFFDYN. For example in the machinery sector those effects show up in the years 1985 to 1989.

4.3 Technology: Structuring Horizontally

Besides pointing to vertical sectoral structures the theory of localized technological progress claims that the accessable process frontier is pushed to higher performance levels not uniformly but by the activities of single, technically quite different firms. This leads us to the discussion of sectoral horizontal structures which focuses on the coexistence of different dominant techniques, a concept which will be defined below. The derivation of those structures is based on the following argument and procedure.

4.3.1 Dominant Technologies and Technology Fields

The analysis in 4.2 above has shown that comparing the yearly best-practice frontiers there is no steady progress to higher average performance levels. However, it is still possible to determine whether the best-practice frontier of year $t+1$ is superior to the one of year t. Such superiority shows up when at least some part of the frontier improves and the remaining parts stay put. Whenever this is the case, one will be able to identify the firms and the respective superior techniques which are responsible for this shift and push forward technological progress. On the contrary, whenever the frontier of t stays superior to the one of $t+1$, the best-practice techniques in t are consequently also dominant in $t+1$ where no further technological progress has taken place. Applying this procedure repeatedly over time, one might be able to identify techniques dominating for a longer period representing the highest technological level achieved up to this point of time. The frontier built-up of the dominating techniques of year t is furtheron called the "technology frontier" of period L

In order to display the development of dominant techniques we create 11 samples according to the years 1981 to 1991 for each sector. Sample "81" contains only the 1981 production data of the respective firms whereas sample "82" includes the production data of the firms in 1982 together with the production data of the best-practice firms of 1981. Continuing with this procedure means to include in a year's sample additionally all best-practice techniques of the preceding year.

The dominant techniques identified above can be used to construct a horizontal sectoral structure by distinguishing them by their relative factor use. Additionally, since those techniques represent the technology frontier they may serve as a kind of "technological attractor" for below best-practice firms characterized by comparable input ratios. With this perception one can even go further and define "attraction" or "technology fields" with the dominating techniques as protagonists - although such a concept is to be interpreted carefully. The construction of those fields is implicitly done by the DEA procedure. Here the X-values can be used to assign below-best-practice firms to the respective best-practice technique as described in 3.2.

Tables 2a-c give an account of the dominant techniques that can be observed in the period 1981-91. For each dominant technique the firm-id of the "inventing" firm and the respective capital/labor ratio, K/L, is stated. The later declines in each table from the left to the right. In addition, for each year we state the number of firms which are attracted by the respective dominant technique. Finally, the shaded cells show for which years the respective techniques stay dominant.

From these tables some general results can be drawn. First of all, for all three sectors we find a tendency towards higher capital intensity during time. This can be seen by the number of firms joining the higher capital intensive fields.

Table 2a: Dominant techniques in chemistry

Field:	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
Firm-id:	#709	#709	#406	#709	#581	#581	#581	#581	#581	#581
K/L:	3.5	3.0	2.6	1.3	0.6	0.5	0.4	0.39	0.3	0.28
Year										
81				28			1			4
82				29					4	
83				30					3	
84				29				4		
85				31				2		
86		25					8			
87	24				9					
88						33				
89						33				
90						33				
91			32			1				

Table 2b: Dominant techniques in electronics

Field:	F1	F2	F3	F4
Firm-id:	#053	#369	#369	#499
K/L:	3.5	1.1	0.6	0.3
Year				
81			27	
82			27	
83			27	
84		22	5	
85		25	2	
86		27		
87		25	2	
88		26	1	
89		26	1	
90		26		1
91	15	10		2

Secondly, with respect to the appearance of dominant techniques at least for machinery and electronics those techniques become increasingly more capital intensive. This suggests that to become a best-practice performing firm research in capital intensive "fields" seems to be more attractive.

Table 2c: Dominant techniques in machinery

Field: / Firm-id: / K/L: / Year	F1 #332 83.6	F2 #463 7.2	F3 #174 3.2	F4 #489 0.8	F5 #489 0.7	F6 #489 0.6	F7 #489 0.5	F8 #272 0.2	F9 #437 0.17
81			7				61	3	
82			7			52	11	1	
83			10			52	8	1	
84					71				
85					71				
86	1				68				2
87	1				69				1
88	1				70				
89	2				69				
90	1	8		55	7				
91	2	9		56	4				

Third, the latter result tends to be corroborated by the fact that some of the labor intensive dominant techniques stay dominant over the whole period of investigation but in later years no firms are attracted by them. F9 in machinery is a point in case. Forth, comparing the different dominant techniques it appears that some of them are generated by the same firm such as F4-F7 in machinery by firm #489 or F10-F6 in chemistry by firm #581. This helps to identify technologically dominant firms.

4.3.2 The Local Character of Technological Progress

The apparent horizontal structure can of course be analyzed in many additional aspects such as the development of the average efficiency of the "fields", development of the average K/L ratio of the "fields", etc. For those analyses we refer to our previous work.

With respect to localized technological change however, two aspects seem to be interesting. First, do technology fields represent local technologies in the sense that it is difficult to switch from one field to another? Second, do firms within a technology field follow a rather common path of technological change?

With respect to the first question tables 3a-c show the number of reorientations of firms (i.e. switches between technology fields) with respect to the dominant techniques during the whole period 81-91. Since mainly the cells close to the main diagonal are filled, most reorientations take place between adjacent fields. Those reorientations can be the result of (a) the movement of an inefficient firm towards another technology or (b) the emerging of a new dominant technique on the frontier. These cases can be analyzed by looking additionally on tables 2a-c. For the machinery sector case (a) shows up in 1991, where compared to 1990 three firms leave F5 and join the fields F1, F2 and F4. For case (b) an example is the year 1984 where F5 comes to dominate the sector totally or 1986 where the fields F1 and F9 emerge.

Table 3a: Reorientation in Chemistry

from \ to	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
F1						24				
F2	24				1					
F3										
F4		25					6	1	1	
F5						9				
F6			32							
F7				1	8					
F8				2			2			
F9				1				3		
F10				1					3	

Table 3b: Reorientation in Electronics

from \ to	F1	F2	F3	F4
F1				
F2	15		4	1
F3		30		1
F4				

Here again further analytical steps are possible, such as the average efficiency change of reorienting firms. This might help to get some hints on how and why firms react on changes of the technology frontier. Here again we refer to some previous studies.

Table 3c: Reorientation in Machinery

to / from	F1	F2	F3	F4	F5	F6	F7	F8	F9
F1				1					
F2	1			1					
F3					10		1		
F4		3							
F5	2	8		57					2
F6			3		52				
F7			1		8	54			
F8					1	1	1		
F9					2				

With respect to the second question we analyze the degree and the direction of technological progress of a technology field. In the preceding paragraph we showed that there is a remarkable tendency for inefficient firms to stay within a specific technology field. As a straightforward explanation one could argue that this tendency is caused by the local character of technological progress - in a way that firms within a technology field are bound to a certain trajectory within a narrow range of K/L ratios. This, however, does not necessarily hold for a technology field covering a rather large piece of the frontier. Here it is possible for the inefficient followers to use a broad range of K/L ratios for technological progress without leaving the respective technology field.

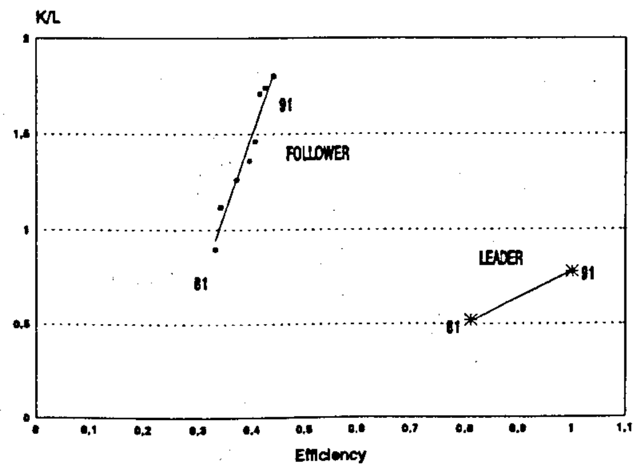

Fig. 2: Development of Dominant Technique and Followers (source: own calculations)

Figure 2 presents the "technological path" of the main dominant technique in machinery on the frontier (LEADER) as well as the average progress of the inefficient firms (FOLLOWERS). It is quite obvious that in this case the frontier moves faster and with a lower K/L ratio towards efficiency than the average of the followers. Even more interesting seems the fact that there is no erratic movement of the followers' K/L ratios that are steadily increasing with improving efficiency. So at least for this technology field (and at least on the average) the "local character assumption" holds.

4.4 Efficiency of Dominant Techniques: Comparing Horizontal Structures Vertically

In this last section we demonstrate a procedure suitable to compare best-practice firms or best-practice techniques. In the DEA model (3) those always are evaluated with 1.0 which implies that they are not comparable in efficiency terms. By applying DEA model (4), however, we determine the measure *0* which makes even this comparison possible. To illustrate this step we investigate wether it is possible to compare dominant techniques in machinery sector. The results are shown in table 4. The respective numbers state to what percentage level the inputs used to run those dominant techniques can be increased proportionally (or can be kept idle) so that the respective technique stays just dominant.

This procedure similarity produces X-values which can be used to detect the most close "rival". For this one can distinguish between rivals on the technology frontier (marked with a "*"table 4 and rivals coming from the inefficient subset.

From this analysis some rather general results can be drawn. First, dominant techniques characterized by rather extreme factor input ratios tend to have higher 0-values. An example for this are F1 and F9. This result is caused by the fact that in those "regions" the slope of the technology frontier - or equivalently the endogenously determined relative factor price ratio - often becomes either zero or infinity.

Consequently, the economic value of one factor is zero in the respective region allowing the firm to keep comparatively more of it idle.

Table 4: Efficiency of Dominant Techniques in Machinery: θ-values

Field: Firm-id: K/L: Year	F1 #332 83.6	F2 #463 7.2	F3 #174 3.2	F4 #489 0.8	F5 #489 0.7	F6 #489 0.6	F7 #489 0.5	F8 #272 0.2	F9 #437 0.17
81			1.05*				1.44*	1.07*	
82			1.03*			1.02*	1.09*	1.07*	
83			1.03*			1.02*	1.09*	1.07*	
84					2.15				
85					1.54				
86	5.43*				1.75				1.46*
87	1.06				1.82				1.46*
88	5.39				1.80				
89	5.39				1.60				
90	3.31*	1.13*		1.10*	1.01*				
91	2.45	1.13*		1.10*	1.01*				

Second, the magnitude of the θ-value gives some hints on the possible duration of the dominance. For example F6 with a 1.02 appears in 1982 and disappears in 1984. Contrariwise, F5 appears in 1984 with 2.15 and then keeps dominant until 1991. Third, related to the previous point, whenever the development of the θ-value of a dominant technique shows a decreasing tendency the likeliness for the appearence of a new adjacent dominant technique increases (see F5 in 1985 and 1989). Finally, low θ-values with frontier competition (marked with "*") suggests that this technique is very likely to be overtaken (e.g. F3, F6, F7 and F8 in 1983). Contrarywise is the case where a low θ-value is combined with no frontier competition. Here the upcoming technique might become best-practice without dominating the technique under consideration. In our example this case does not show up clearly, F5 in 1989 is comparably close to this.

5. Conclusion

This paper presents an empirical approach towards detecting of industrial structures and their dynamics. The theoretical foundation is modem innovation theory where the concept of localized technological progress underlines that firms' activities are the driving force for technological development and that those advances are local. Contrasting this concept with the neoclassical perception of technological progress has important consequences for any empirical analysis in this area. Neoclassical methods sticking to equilibrium and representative agent assumptions are only poorly suitable to detect industry structures caused by localized technological change.

In order to cope with this lack we introduce a non-parametric linear programming method, DEA, which can be applied to analyse productive structures. We show how the results of this method can be applied to detect vertical and horizontal structures. More specifically we introduce procedures to determine dominant techniques and corresponding technology frontiers. With these concepts the development or even evolution of industry structures can be traced. In another variant of DEA we show that it is even possible to find measures which help to distinguish best-practice firms or techniques by an efficiency criterion.

The application of this method is illustrated for three selected sectors of the German industry. We show how certain characteristic structures and their development can be detected and interpreted. Of course, there are still some more analytical steps which can be performed with our DEA results. We skipped them in order to give a more comprehensive overview.

Besides those additional steps, most important, the DEA results should be used in other analyses. For example, it is evident that efficiency parameters and horizontal structures should be related to variables for the innovative activities of firms as has already been done in Cantner/Hanusch/Westermann (1995) where significant positive estimates were achieved. Also the relation between economic success (measured by profits, market shares etc.) seems to be interesting; Bemard/Cantner/Hanusch/Westermann (1995) have found some positive evidence in this respect. The development of vertical industry structures and their relation to catch-up activities geared by the ability to absorb spillover effects has been investigated in Cantner (1995).

Besides this, of course, the effects of industry entry and exit, of intersectoral spillover effects, of public policy intervention, and even of regional specifities provide a huge field of further applications of DEA and our suggested procedures. From the methodological side it is also planned to extend the analysis in order to take into account scale effects (see Thore (1995)) and stochastic features.

References:

Ali A.I. and C.S. Lerme (1990), Data Envelopment Analysis Models: a Framework, Working Paper, School of Management, University of Massachusetts at Amherst. .

Andersen P. and N.C. Petersen (1989), A Procedure for Ranking Efficient Units in Data Envelopment Analysis, Dep. of Management, Odense University, no.11.

Antonelli C. (1994a), The Economics of Localized Technological Change, Kluwer Academic Publishers.

Antonelli C. (1994b), Localized Technological Changes: A Model Incorporating Switching Costs and R&D Expenses with Endowment Advantages, in: Shionoya Y. and M. Perlman (1994) (eds), Innovation in Technology, Industries, and Institutions, Michigan University Press.

Atkinson A.B. and J.E. Stiglitz (1969), A New View of Technological Change, Economic Journal, vol.79, 573-78.

Banker R.D., A. Charnes and W.W. Cooper (1984), Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis, Management Sci., vol 30, pp.1078-92.

Bernard J., U. Cantner, H. Hanusch and G. Westermann (1994), Technology and Efficiency Patterns - A Comparative Study on Selected Sectors from the French and German Industry, Working Paper #121, University of Augsburg.

Bernard J., U. Cantner and G. Westermann (1995), Technological Leadership and Variety - A Data Envelopment Analysis for the French Machinery Industry, forthcoming in: Thore (1995), special issue of the Annals of Operations Research.

Böhm K.(1978), Lineare Quotientenprogrammierung - Rentabilitätsoptimierung, Frankfurt a.M.: Haag+Herchen Verlag.

Cantner U., (1995), Technological Dynamics in Asymmetric Industries, University of Augsburg, mimeo.

Cantner U., H. Hanusch and G. Westermann (1996), Detecting Technological Performance and Variety - An Empirical Approach, forthcoming in: Helmstädter/Perlman (1996).

Caves R.E. and D.R. Barton (1990), Efficiency in U.S. Manufacturing Industries, Cambridge: MIT Press.

Charnes A. and W.W. Cooper (1962), Programming with Linear Fractional Functionals, Naval Research Logistics Quarterly, vol.9, pp.181-86.

Charnes A. and W.W. Cooper Rhodes (1978), Measuring the Efficiency of Decision Making Units, European Journal of Operational Research, vol.2, pp.429-44.

Charnes A. and W.W. Cooper (1984), The Non-Archimedean CCR Ratio for Efficiency Analysis: A Rejoinder to Boyd and Färe, European Journal of Operational Research, vol.15, pp.333-34.

Cohen W. and Levinthal (1989), Innovation and Learning: The Two Faces of R&D, Economic Journal, vol.99, pp.569-96.

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

Dosi G. (1988), The Nature of the Innovative Process, in: Dosi et al. (1988), pp.221-38.

Dosi G., C. Freeman, R. Nelson, G. Silverberg and L. Soete (1988), Technical Change and Economic Theory, London, New York: Pinter Publishers.

Farrell M.J. (1957), The Measurement of Productive Efficiency, Journal of the Royal Statistical Society, Series A, vol.120, pp.253-81.

Freeman C. and L. Soete (ed), (1990), New Explorations in the Economics of Technological Change, London, New York: Pinter Publishers.

Freeman C. and L. Soete (1987), Factor Substitution and Technical Change, in: Freeman C. and L. Soete (eds), Technical Change and Full Employment, London: Basil Blackwell, 36-48.

Kendrick J.W. (1956), Productivity Trends: Capital and Labor, Review of Economics and Statistics, Vol.38, pp.248-57.

Nelson R.R. and S. Winter (1962), An Evolutionary Theory of Economic Change, Harvard University Press.

Ott A.E. (1959), Technischer Fortschritt, in. Handwörterbuch der Sozialwissenschaften, Bd.10, Stuttgart, pp. 302-16.

Stiglitz J.E. (1987), Learning to Learn Localized Learning and Technological Progress, in: Dasgupta P. and P. Stoneman (1987) (eds), Economic Policy and Technological Performance, Cambridge University Press.

Thore S. (1995), Economies of Scale in the U.S. Computer Industry: An Empirical Investigation Using Data envelopment Analysis, Journal of Evolutionary Economics, forthcoming.

Verspagen B. (1990), Localized Technological Change, Factor Substitution and the Productivity Slowdown, in: Freeman C. and L. Soete (eds), New Explorations in the Economics of Technological Change, London, New York: Pinter Publishers, 193-211.

1. For an overview see Caves/Barton (1990).

2. See for example Caves/Barton (1990).

3. See David (1987) who argues that the elasticity of substitution of the firm specific production function has to be less than teh one of the socalled fundamental production function describing as a short-run concept the possible, but yet not accessable, latent techniques.

4. See Kendrick (1956) and Ott (1959).

5. This procedure is also known from activity analysis.

6. An overview over linear fractional programming is given in Bõhm (1978).

7. There obviously exists a range of possible model specifications where the one chosen is known as CCR. Applying this one has to keep in mind that possible scale inefficiencies are included in the technical inefficiency measure.

8. Of course, one should here distinguish two vectors e^T for inputs and output respectively which contain s and i elements respectively. To ease notation we do not take account of this. Further analysis is not affected.

9. See Charnes/Cooper (1984).

10. This comparision requires the assumption for production techniques to be (infintely) divisible. Peter Swann and Ed Steinmueller made the point that this assumption seems to be at odds with the notion of localized technological progress. This problem can easily be avoided by using the primal of the envelopment form (3) - the productivity form - which implicitly compares firms by a kind of total cost per unit of output using endogenous factor prices or aggregation weights. In fact, here an index for total factor productivity for firm l is determined where the aggregation weights are computed in a way they represent a factor price ratio at which all best-practice firms towards firm l are allocative efficient. Consequently, θ_l alternatively to the interpretation above states the percentage level to which "costs" per unit output of firm l have to be reduced so that this firm becomes as "cost-efficient" as its respective best-practice firms. Although this procedure would resolve the problem of divisibility of production processes it requires the assumption that those relative factor prices (or relative marginal factor productivities) at which all best-practice firms to firm l are allocative efficient are the appropriate measure to evaluate the below-best-practice firm l.

11. We restricted the number of inputs to two in order to ease the presentation of the methodology. One advantage of the DEA is the possibility to consider multiple in- and outputs. But an increasinging use of the analytical power of our method makes the graphical presentation more difficult if not impossible.

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