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Technological Dynamics in Asymmetric Industries

R&D, Spillovers and Absorptive Capacity

von

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Abstract

The analysis we present is concerned with the technological dynamics within economic sectors. A simple model of the technological interaction between best-practice and below best-practice firms is used to identify the mechanism of catching-up and falling-behind. Here the spillover effects and the absorptive capacity of firms are of major importance. We test the model empirically applying OLS and non-linear least squares on firms'data from the German electronics and machinery sectors. We can show that the model's mechanism seems to be relevant for a technologically determined structural change in these sectors although considerable differences are detected.

Keywords: technological dynamics, catching-up, technological spillovers, absorptive capacities

JEL-number: O3

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1.Introduction

Industrial economics is quite a rich source of problems and "puzzles" for economic theorizing. One of the most discussed issues is certainly the persistence of different performances among firms (and plants) within a sector - either with respect to technological or economic performance. Other issues are related to the dynamics of entry and exit, sectoral specifities in industrial structures and their change, the co-existence of firms of different sizes, etc.

This paper cannot cope with all of these interesting questions but will focus on the technological performance of firms and the persistence and/or only slow motion of technological structures within sectors. With respect to the latter the mechanism which leads to more divergence or convergence of technological levels is of special interest. We will argue that firms' respective technological level is the outcome of firm-specific R&D-activities, individual learning effects and the result of the respective ability to use technological spillovers from other firms. Thus, the firm-specific accumulation of technological know-how is responsible for persistent technological differences and technology determined industrial structures. Economic factors such as relative factor prices do have only - at least in the short and medium run - a minor impact on these structures. Nevertheless, firms "interact" with each other by the means of technological spillovers which may provide heterogeneity not to become too disperse and technological levels not diverge infinitely or even converge.

On this basis we will show that the changes in the sectoral structures of technological performance can be explained the very existence of technological spillovers whose magnitude are responsible for processes such as catching-up and falling behind. An quite important result is that the relative technological position of firms does influence their possibilty of catching up in a nonlinear fashion. For these effects statistically significant regression results for the German electronics and machinery industry are found.

We proceed as follows: Section 2 present a theoretical framework able to explain different technological performances, the posibility of quite stable technological differences among firms and the mechanism of catching-up and falling-behind. Section 3 investigates whether the modelling of technological asymmetries and dynamics of section two holds when applied to empirical data. Some concluding remarks close our paper with section 4.

2. Technological Levels, Convergence and Divergence

There exists now a well established body of literature stressing that the speed and direction of technological progress is not to be considered as solely reactive on economic factors as several version of a demand-pull approach suggest, e.g. change in relative factor prices, change in the structure of demand etc. Besides these aspects, however, one has to take into account (a) from the technological side the focussing character of scientific principles and methods, i.e. technological paradigms (Dosi (1988)), and (b) from the side of (active) search procedures of agents a bounded rationality with limited abilities to screen all possible directions of progress (Simon (1979), Nelson/Winter (1982)). Consequently, one has to observe a quite heterogeneous structure of technological performance of firms with often firm-specific, tacit, not easily transferable know-how stocks and path-dependent possibilities for further advances. An important consequence of this perception is that just by the cumulative nature of technological progress technological leads and lags may well be persistent even without any legal protection. One can even go a step further and suggest that even when all firm have access to the technological know-how of their competitors they would differ considerably in their technological performance.

On this basis technological progress is to be considered as the innovative and imitative activities of heterogeneous firms. Despite this heterogeneity, however, one can observe that firms nevertheless apply technologies which are identical or at least show highly common features. Which forces are responsible for this result? From an purely technological point of view the prevailing common technological bases or paradigms reduce the variety of technological approaches. Thus, leading firms try to exploit existing technological potentials[1], below best-practice firms try to imitate technology leaders. From an economic point of view one may additionally ask how relative prices fit into this perception? First, according to the cumulative and paradigm-based feature of technological progress one cannot expect to observe price-related substitution effects among several techniques practiced - at least not in the short or medium-run. Even with relatively significant relative price changes the underlying technological principles of the applied knowledge-base bound the direction of progress in a quite narrow development paths. Second, persistent shocks on relative prices, however, might exert rather irreversible effects on the direction and choice of certain technological concepts.

Concerning sectoral structures this approach to technological progress has the consequence that although the technological development is highly firm specific, technological heterogeneity of firms is reduced by (a) the usage of the same technological principles and search routines and (b) by the rather long-run impact of relative prices.

In what follows we try to formalize some of the ideas just presented with the help of a simple model.[2] Our focus will be solely on the technological relationships among heterogeneous firms, while the impact of relative price changes will be assumed to be neglegible.

In the following we consider a certain economic sector with a number of firms with heterogeneous performances. The technological level T of a firm j at time t is broadly determined by three factors:

$$T_t^j = F(N_t^j, E_t, S_t) \tag{1}$$

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1 They may even try to create new technological potentials. See Cantner/Pyka (1995).

2 A comparable model is used by Verspagen (1992) who applies it to the convergence/divergence of economies.

Here E represents all the influences and feedbacks from the economic sphere, i.e. the market, which affect the firm's ability to persue further technological improvements, e.g. relative factor prices, sales, profit, market share, etc. Variable N^j takes account of all those firm j specific effects which change only slowly over time - if at all. Here we might think of quite tacit factors such as talent or certain routines. Finally, variable S represents all non-market relationships between firms and here especially we consider technological spillovers. Those effects S should represent the focussing impact of technological paradigms which constrains the development paths.

Assuming that all firms act within the same technology, technologically different performances can be explained by different technological levels at time t accumulated in the past. In order to compare those different technological performances the technological levels of always two firms could be compared. The respective ratio then gives account of relative distance between the two - or in other words the technology-gap. Taking the logarithm of this ratio provides that technologically equivalent firms show up with a technologcal gap of 0. The technological gap G between two firms i and j at time t is then defined as:

$$G_t^{ij} = \ln\left[\frac{T_t^i}{T_t^j}\right] \tag{2}$$

The development of this gap over time is then given as follows where the "^" is used for percentage changes:

$$\dot{G}^{ij} = \hat{T}^i - \hat{T}^j \tag{3}$$

Given these basic formal elements one has to specify the influencing variables E, N and S. To do this for we restrain the analysis on two firms, A and B.

Firm *A* is assumed to be technologically dominant and firm *B* lagging. This can be explained by some historical chance which gave *A* the lead. Both firms are engaged in persuing R&D activities. Those activities further the technological knowhow and the innovativeness of each firm which in turn does also influence the respective market success. For this process we have to distinguish the three influences *E*, *N* and *S* above.

For the variables N^j we assume in each period *t* constant influences $\bar{R}^j$, $j=\{A,B\}$. They can be interpreted either as the constant influence of some firm specific talent or certain R&D expenditures spent each period in an unchanged amount.[3] Moreover, for those expenditures it is assumed that the technological opportunities to be explored are infinte and the respective periodic increments of $\bar{R}^j$ on T^j are constant.

For the technological spillover effects we assume that only the backward firm can learn from the technology leader but not the other way round.[4] Moreover we assume that the ability to recognize and understand those spillovers is dependent (a) on the technology gap between *A* and *B* as well as (b) on the ability of *B* to understand the technological know-how of *A*. With respect to (a) on the one hand it seems plausible that with a low gap between *A* and *B* the benefit of spillovers are quite low - *A* and *B* are close together and there is not much new *A* has to provide. On the other hand whenever there is a large *G* it might be hard for *B* to understand all of the sophisticated know-how *A* has already accumulated - the benefit of spillovers for *B* are supposed to be low again. However, in between these two cases there seems to be a technological distance where the effects of technological spillovers have a maximum level. Consequently, one can construct the effcets of spillovers as dependent on *G* as a bell-shaped function with 0 benefit in $G=0$, increasing benefits up to a certain G^*, and steadily decreasing benefits with higher technological gaps. With respect to (b) we assume that it is not only the technology gap but also the backward firms absorptive capacity (Cohen/Levinthal (1989)) which

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[3] Aspects of financing those amounts are not considered here and are assumed to be not a relevant issue.

[4] For using this concept see also Verspagen (1992).

determines the magitude of spillover benefits. The larger those capacities the higher the influence of spillovers on the own technological level. For the bell-shaped spillover function this implies that the absortive capacity provides for the height of the function.

With respect to the constant influences and the spillover effects the development of the respective technological level T^j is given as follows:

$$
\begin{aligned}
\hat{T}^A &= \bar{R}^A \\
\hat{T}^B &= \bar{R}^B + aGe^{-\frac{G}{c}}
\end{aligned}
\tag{4}
$$

The second term on the RHS for firm B represents the spillover with parameter a taking account of the potential spillovers and parameter c of the absorptive capacity.

In a next step we want to take into account the economic effects on the development of T^j. Our special focus is how the higher (lower) success of firms in the market provides for higher (lower) innovative activties in the next period. Here, the range of possible modelling is quite large and dependent of the assumption of the underlying market: Is it a market which is growing and where the relative technological position allows an above or below average growth of firm's sales with all the effects on next periods R&D budgets? Is the market stagnant and the relative technological position takes determines the firm's market share? Is it only the profits which constrain firms to change their R&D budgets for the future?

It would be far beyond this paper to discuss all these cases. Therefore we want to confine ourselves on the case where the relative technological position determines an above or below average growth of sales.[5] Formally, the average growth rate of the market is exogenously given with $\hat{m}$. The firm specific growth of sales is higher (lower) than this

[5] The other modelling possibilities do in fact modify our results only slightly so that for a qualitiative analysis is seems appropriate to proceed in the suggested way.

rate if the firm has an above (below) average technological level. Formally this relation can be stated as follows:

$$\begin{aligned} \hat{u}^A &= \epsilon \ln\left[\frac{T^A}{T^B}\right] + \hat{m} \\ \hat{u}^B &= \epsilon \ln\left[\frac{T^B}{T^A}\right] + \hat{m} \end{aligned} \tag{5}$$

$\hat{u}^j$, $j=\{A,B\}$, is the firm specific growth of sales and the parameter ϵ represents the elasticity of this growth with respect to the change of the technology gap.
This growth of sales can have two different effects:

(1) It implies that we have to consider a kind of cumulative learning where a growing market allows firms to apply its technology more efficiently. Therefore, the growth of sales provokes cumulative learning effects, learning-by-doing or socalled **Verdoorn**-effects.

(2) Higher sales allow for higher additional R&D expenditures with all the positive influences on further technological development. Thus, our assumption above that financing R&D is supposed to be no problem is somewhat relaxed here.

In fact, independent of the interpretation what we assume and describe here is the mechanism of a **vicious circle** with technological progress feeding economic success which in turn promotes further technological advances.

The effect of the growth of sales on the development of T^j is represented by the parameter λ which is to interpreted either as the learning- or Verdoorn-parameter or as the share of sales growth used for additional R&D. This parameter is assumed to be identical for the two firms under consideration.

Considering the *E*-, *N*- and *S*-effects the development of the respective technology levels T^j is given as follows:

$$\hat{T}^A = \bar{R}^A + \lambda\hat{u}^A$$
$$\hat{T}^B = \bar{R}^B + \lambda\hat{u}^B + aGe^{-\frac{G}{c}} \qquad (6)$$

With the definition of $\dot{G}$ in (3) we get for the development of the technological gap:

$$\dot{G} = \bar{R}^A - \bar{R}^B + 2\lambda\epsilon G - aGe^{-\frac{G}{c}} \qquad (7)$$

For interpreting this equation we have to distinguish two different forces. First, diverging effects are given by the difference in $\bar{R}^j$ and the effect from the growth of sales. Second, spillover effects tend to decrease the technology gap and therefore lead to convergence. One may ask now which of these effects comes to dominate, whether the technological level of the two firms diverges or converges or whether there even exists a stable technological distance between both. In order to answer this question one has to find solutions where we have $\dot{G}=0$:

$$\bar{R}^A - \bar{R}^B + 2\lambda\epsilon G = aGe^{-\frac{G}{c}} \qquad (8)$$

The possible solutions for (8) can be represented graphically. At least one has to consider here there different scenarios. Whenever the absorptive capacity of B is low enough (8) will have no solution and the technological levels of the two firms diverge more and more. In a second case the absorptive capacity of B is just as high that there is a single solution for a equilibrium technology gap. However, this case is quite accidental and, as can be shown, is only a special case of our third scenario. We therefore want to discuss only the analytically most interesting scenario where two different equilibrium gaps occur. Figure 1 shows the solutions graphically. Figure 2 shows the respective phase diagram.

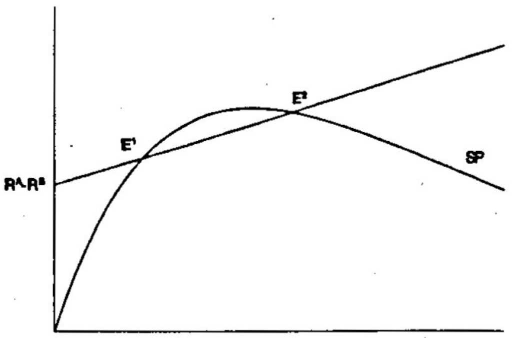

Figure 1

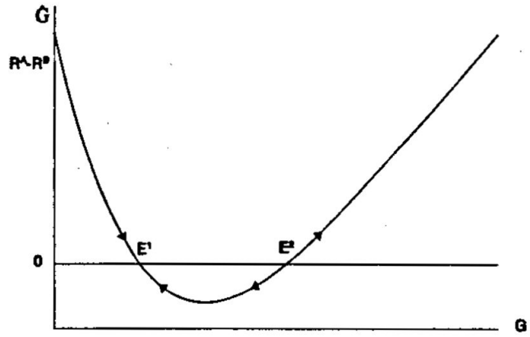

Figure 2

The LHS of (8) is a linear function starting in $\bar{R}^A$-$\bar{R}^B$. The RHS of (8) is the bell-shaped spillover function. With an appropriate c the spillover function will intersect the linear function twice. Stability analysis shows that the equlibrium point E_1 ist stable whereas E_2 is unstable. With any deviation from E_1 to the left diverging effects come to dominate and push the technoogy gap back to E_1; with a deviation to the right dominating spillovers will also force the gap back to E_1. Any deviation from E_2 however will be reinforced. A deviation to the left will be reinforced by spillover effects pushing the gap to E_1; with a deviation to the right the $\bar{R}^j$-differences come to dominate spillover effects and the gap diverges continously.

3. Empirical Estimation

The model presented in section 2 will be tested empirically. For this purpose two steps are necessary. First, for specific sectors one has to determine the technological levels and/or the relative technological positions of firms and their change over time. Second, using these results a regression analysis can be applied in order to test the model above.

3.1 Procedure and Database

Technology gaps and technology structure

As to the first step we rely on a procedure suggested by Cantner/Hanusch/Westermann (1996) and Bernard/Cantner/Westermann (1995). We cannot go here into a detailled discussion of this approach and refer to the original work. However, a short description of the results obtained and the relation to our analysis here should nevertheless be given.

The approach attempts to determine the heterogeneous technological performances of firms belonging to the same sector. Applying a non-parametric linear programming method a best-practice-technology frontier is determined. For this purpose data for the real input factors and the real outputs are used. The non-parametric specification allows to consider each firm producing with a Leontief-production function which are parametrically quite different among firms. The respective linear programm for a specific firm 1 reads as follows:

$$\begin{aligned} \min \quad & \theta_l - \epsilon e^T s^+ - \epsilon e^T s^- , \\ s.t. \quad & \\ & Y\lambda - s^- = Y_l , \\ & \theta_l X_l - X\lambda - s^+ = 0 , \\ & \lambda, s^+, s^- \geq 0 . \end{aligned} \tag{9}$$

θ_l is the relative efficiency of firm l with $\theta \in]0,1]$. With $\theta_l = 1$ firm l is best-practice and with $\theta_l < 1$ the firm is below best-practice. s^+ and s^- are excess inputs and output-slacks respectively, e^T is a vector containing only 1 and ϵ is a socalled non-archimedian constant which is necessary to identify cases where firms are determined as best-practice although they are obviously not.[6] Y and X are the matrices of all n firms' outputs and inputs

[6] On this issue see Cantner/Hanusch/Westermann (1996).

respectively, 7, and X_t are the vectors of firm's *l* Outputs and inputs. X is a vector which contains the respective weights of firms *n* against which firm *l* is rated.

Computing this linear programm for all *n* firms delivers a number of results:

(1) The distance from the best-technology-frontier in period *t* (which contains the best technologies up to period *t*)[7] [8]may serve as a proxy for the technology gap *G* between the frontier and the respective firm. In (9) this measure is given by a Parameter *6* which however is modified to the parameter i? With those measures we get an account of the vertical structure of the respective sector.

(2) With the help of the parameters X it is possible to determine certain technology fields, i.e. a number of firms which apply the same technology.[9] Consequently, we here detect the horizontal structure of the sector.

(3) For each period under investigation the firms' technology gap can be computed. The sequence of those gaps gives than an account of whether the firm catches up to the technology frontier or whether it falls behind. An increasing (decreasing) t implies a catch-up (falling behind).

Testing technological dynamics

Using these results we will test the model outlined above. We will distinguish different analyses. As the variable for the technology gap we use the values for i. Since these are constrained on the interval]0,1] we transform these values by taking the negative of the

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7 For the different frontier concepts used in DEA see Cantner/Westermann (1995a, 1995b).

8 See Cantner/Hanusch/Westermann (1996) for a discussion of this issue.

9 A technology is here defined by a certain input ratio.

logarithm of ι. We obtain a variable g which is the higher the larger the technological gap between the firms. Catching-up (falling-behind) processes lead to a negative (positive) $\dot{g}$.

(1) Different model specifications will be tested:

$$(E1)\quad \dot{g}_{it} = \alpha_1 + \beta_1 g_{it0} + \epsilon_{it}$$

$$(E2)\quad \dot{g}_{it} = \alpha_2 + \beta_2 g_{it0} + \gamma_2 AC_{it} + \epsilon_{it}$$

$$(E3)\quad \dot{g}_{it} = \alpha_3 + \beta_3 g_{it0} + \gamma_3 AC_{it} + \delta_3 RDD_{it0} + \epsilon_{it}$$

$$(E4)\quad \dot{g}_{it} = \alpha_4 + \beta_4 g_{it0}\, e^{\left(\gamma_4 \frac{g_{it0}}{AC_{it}}\right)} + \epsilon_{it}$$

$$(E5)\quad \dot{g}_{it} = \alpha_5 + \beta_5 g_{it0}\, e^{\left(\gamma_5 \frac{g_{it0}}{AC_{it}}\right)} + \delta_5 RDD_{it0} + \epsilon_{it}$$

The equations (E1)-(E3) are estimated using ordinary least squares, the equations (E4)-(E5) with nonlinear least squares. The α_n, β_n, γ_n and δ_n are the parameters to be estimated. $\dot{g}_{it}$ is the change of the technology gap of firm i in period t. g_{t0} is the technology gap of firm i at the beginning of period t. AC_{it} represents the absorptive capacity of firm i in period t. RDD_{it0} takes account of differences in R&D-expenditures with respect to the technology leader. ϵ_{it} is the error term of the equation of firm i in period t.

For the respective coefficients according to the model of section 2 we expect the following signs:

$\beta < 0$, $\gamma < 0$, $\delta < 0$, α may take either sign.

(2) With respect to the technology gap to be investigated we also want to take into account the various technology fields of the respective sectors. Therefore in a first group of estimations differences in R&D expenditures, in R&D Capital Stocks etc. will be taken with respect to the average of the whole technology frontier. In a second group of regressions those differences are calculated only within a specific technology field. On this basis we will able to take account of technology specific effects.

For estimating these equations we consider the change in the technological gap from 1985 to 1991. For stock variables to be included in the analysis we take their average during the 7-year period. For fiow variables the respective sums are determined.

Data

The respective sectors we investigate are the machinery and the electronics sector in Germany from 1985 to 1991. For the determination of technology gaps and technological structures the inputs labour, Capital and material as well as a single Output variable are used. Labour is measured in effective hours worked, Capital is the balance shee position "fixed assets", materials is the deflated gains-and-loss position "raw materials and supply". As Output we use the deflated sum of "total sales", "inventory changes" and "internally used firm Services" from the profit&loss acounts. Those data are all drawn from the annual reports of the respective firms. As to the firms we have only share holder Companies, with 28 firms in electronics and 65 firms in machinery. The major constraint on these numbers is the availability of firm specific R&D data.

For the regression analyses we use the following variables. The absorptive capacity *AC* is approximated altematively with the accumulated R&D Capital stock per working hour of,the firm, $SRDSL^{W}$, and the number of R&D-personel in total working force,

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[10] The R&D capital stock *RDS* has been determined by the perpetual inventory method. The real R&D expenditures are *RD* and the degressive depreciation rate is 15%: $RDS_{it}=RD_{it}+0,85*RDS_{it'}i.$

SRDWORK. For $RDD_{\ddot{U}}$ with use the differences of R&D expenditures, *RD,* and altemati-vely the differences in the R&D Capital Stocks, *RDS.* The firm specific R&D data are provided by a database collected by the Stifterverband.

3.2 Estimation Results

The estimation results for the respective equations are given in tables 1-3. Due to the transformation of the efficiency parameter negative coefficients indicate that the technology gap is reduced. For equations E1 to E3 we use OLS whereas for E4 and E5 non-linear regression analysis is applied. For deriving these results we run several estimations. First, we provide a panel analysis with all years encluded from 1985 to 1990. In Order to get rid of some uneven development within this 5 year period we estimated whether the cumulated effort for the years 1985 to 1990 has been responsible for the change in the technology gap from 1985 to 1991. Finally , in order to cope with accidentally biased gap measures for 1985 and 1991, we computed the average for the first as well as the last three years and analyzed this change. We do not report on the third alternative which is from an qualitative point of view quite similar to the second. We also do not show the figures of the first alternative because the results are comparatively worse - for the reason just mentioned.

Considering only the R^2-values it is quite obvious that the results for electronics are considerably better than those for machinery. This can be explained by two effects. First, generally one has to recognize that the catch-up and falling-behind processes in machinery are of only a small magnitude compared to electronics. The structure within machinery is more stable. Second, the spillover model we test suits better to the innovative activities in electronics than in machinery. We will come back to this issue later.

For machinery the estimation results show that in all models except E3 the constant term is significantly positive which points to the general tendency of falling behind. In all models the technology gap is significantly negative which implies that with a larger initial gap catch-up is more easily accomplished - spillover effects seem to work. Considering the effects of absorptive capacity proxies in the linear models (E2 and E3) the results are rather poor (except in E3 when we use *SRDSL*) but they all have the expected sign. A higher value of this measure leads to catch-up. Here, as in the non-linear models below, the proxy *SRDSL* tends to perform better than *SRDWORK*.

Table 1: Regression results machinery (t-values in brackets)

model	const.	gap g_i	absorptive capacity AC_i		R&D-difference RDD_i	R^2
			SRDSL	*SRDWORK*		
E1	0.268 (13.24)	-0.039 (-1.99)				0.06
E2	0.273 (12.85)	-0.040 (-2.02)	-0.002 (-0.79)			0.07
E2	0.270 (13.15)	-0.04 (-2.01)		-0.0001 (-0.66)		0.07
E3	-1.70 (-1.52)	-0.083 (-2.66)	-0,02 (-1.96)		1.98 (1.77)	0.11
E3	-0.84 (-0.83)	-0.064 (-2.16)		-0.0001 (-1.23)	1.10 (1.09)	0.08
E4	0.34 (10.48)	-0.535 (-2.915)	-0.366 (-4.937)			0.16
E4	0.34 (10.26)	-0.533 (-2.761)		-0.519 (-4.811)		0.16
E5	0.64 (2.19)	-0.577 (-3.06)	-0.394 (-4.706)		-0.289 (-1.029)	0.18
E5	0.62 (2.11)	-0.572 (-2.89)		-0.555 (-4.631)	-0.270 (-0.960)	0.17

The general tendency to fall back (as given by the constant) can be explained by some firm specific effects such as differences in R&D expenditures which represent firm specific routines. In model E3 these effects are not significant and show even the wrong sign.

Considering the non-linear models E4 and E5 improves the estimation fit quite considerably. The bell-shaped spillover function shows up significant and with the expected signs concerning the gap and the measure of absorptive capacity. This implies that firms with a medium level of technology gap and a considerably high absorptive capacity will do the fastest catch-up. In E5 the firm specific effects of R&D differences now show the expected sign although the significance is quite low.

For the electronics sector (table 2) except in model E5 the constant term is positive although not always highly significant. For the technology gap we always find a negative sign indicating that catch-up is more easily accomplished with a higher gap.

Table 2: Regression results for electronics (t-values in brackets)

model	const.	gap g_i	absorptive capacity AC_i		R&D-difference RDD_i	R^2
			SRDSL	*SRDWORK*		
E1	0.048 (0.491)	-0.107 (-1.45)				0.08
E2	0.050 (0.497)	-0.107 (-1.42)	-0.0001 (-0.246)			0.08
E2	0.050 (0.495)	-0.107 (-1.42)		-0.0001 (-0.229)		0.08
E3	1.790 (3.021)	-0.074 (-1.12)	0.003 (2.84)		-1.71 (-2.972)	0.33
E3	1.760 (3.054)	-0.074 (-1.13)		0.0001 (2.87)	-1.68 (-2.99)	0.33
E4	0.135 (1.463)	-0.318 (-2.874)	-0.570 (-2.332)			0.23
E4	0.107 (1.103)	-0.262 (-2.553)		-0.657 (1.834)		0.19
E5	-0.06 (-0.28)	-0.437 (-2.894)	-0.759 (-2.685)		0.216 (1.138)	0.26
E5	-1.38 (-3.11)	-1.25 (-3.45)		-5.11 (-5.432)	1.32 (3.067)	0.42

In the linear models E2 and E3 the proxies for absorptive capacity are either poorly significant or do not have the expected sign. With respect to R&D differences in model E3 the coefficinet significantly shows the expected negative sign indicating that lagging firms with compared to frontier firms lower R&D budgets do harder in catching up. As in machinery, the estimation fit improves considerably when we use the non-linear models E4 and E5. The spillover function again is significant and has the expected signs. However, in E5 compared to E3 the coefficient of RDD_i is now significantly positive.

For both sectors we find that due to the R^2-values and the t-statistics for the coefficients the non-linear equations seem to be a better explanation for the structural dynamics than the linear models. However, such a statement could only be made when the respective models are nested which is clearly not the case when we have different functional forms - i.e. linear versus non-linear functional relationships. In this case the usual procedure is to compute the N- or Cox-statistic which implies that we test the hypothesis H_0 that equation i is a better explanation against the hypothesis H_1 that equation j is a better explanation. We perform this step in accordance to the work of Pesaran/Deaton (1978) which is also found in Greene (1993). In the following we test always the linear and the non-linear equations which use the same set of variables, i.e. E2 with E4 and E3 with E5. The following table shows the results where we always state the t-statistics.

Table 3: Cox-statistics for the linear versus non-linear models

H0 H1	*E2* *(SRDSL)*	*E4* *(SRDSL)*	H0 H1	*E3* *(SRDSL)*	*E5* *(SRDSL)*
E2 *(SRDSL)*		E: 0.60 M: -0.23	*E3* *(SRDSL)*		E: -1.79 M: -2.72
E4 *(SRDSL)*	E: -23.04 M: -29.67		*E5* *(SRDSL)*	E: -0.18 M: -9.51	
H0 H1	*E2* *(SRDWORK)*	*E4* *(SRDWORK)*	H0 H1	*E3* *(SRDWORK)*	*E5* *(SRDWORK)*
E2 *(SRDWORK)*		E: 0.076 M: 0.023	*E3* *(SRDWORK)*		E: -1.34 M: -1.51
E4 *(SRDWORK)*	E: -22.51 M: -30.65		*E5* *(SRDWORK)*	E: -2.48 M: -19.19	

Concerning the test of E2 against E4 the result is straightforward; for both machinery and electronics the hypothesis that E2 fits the data better has clearly to be rejected, because the appropriate values are significantly different from 0. The hypothesis that equation E4 is superior to E2 cannot be rejected, the t values are close to 0. For the comparison of E3 and E5 the results are not clear-cut. In electronics neither formulation is superior (at the 5% level), they both seem to fit the data. In machinery, we have a clear-cut dominance of E5 (SRDWORK) over E3 (SRDWORK). For E5 (SRDSL) and E3 (SRDSL) we find the result[11] that for both the H_0 has to be rejected. Summarizing these results, there seems to be evidence for a superior explanation of the non-linear model.

In a final estimation we use models E3 and E5 to investigate whether the influence of technology fields on the structural dynamics is significant. This is accomplished by the help of RDD_i which is now measured towards the technology leader in the respective technology field.

Table 4: Regression results for machinery and electronics considering technology fields (t-values in brackets)

sector/model	const.	gap g_i	absorptive capacity AC_i		R&D-difference RDD_i	R^2
			SRDS/L	*SRDWORK*		
MA/E3	0.795 (6.38)	0.007 (0.338)	-0.002 (-0.804)		-0.77 (-4.232)	0.28
MA/E3	0.801 (6.402)	0.007 (0.356)		0.0001 (0.907)	-0.77 (-4.29)	0.28
MA/E5	0.789 (6.701)	0.0003 (0.00)	0.853 (0.00)		-0.75 (-4.608)	0.28
MA/E5	0.789 (6.724)	0.0002 (0.00)		1.31 (0.00)	-0.75 (-4.610)	0.28
EL/E3	0.62 (1.26)	-0.142 (-1.77)	0.0001 (0.99)		-0.55 (-1.18)	0.12
EL/E3	0.64 (1.3)	-0.143 (1.80)		0.001 (1.05)	-0.57 (-1.22)	0.13
EL/E5	-0.019 (-0.74)	-0.365 (-2.92)	-0.716 (-2.19)		0.161 (0.80)	0.25
EL/E5	-0.547 (-1.882)	-0.506 (-2.60)		-4.07 (-2.24)	0.532 (1.83)	0.27

[11] For a dicussion of cases where both hypotheses are to be rejected see Pesaran/Deaton (1978).

Table 4 shows our results for both sectors. Obviously, for machinery the estmation results on E3 improve whereas for electronics we have to recognize a poorer fit. With respect to the former it is interesting that the coefficient for RDD_i now shows the expected negative sign. Estimating E5 for machinery we find no significant estimates for the spillover function and the results are by and large equivalent to model E3. Here, technology fields specific effects seem to dominate any possible spillover effects. In electronics, we find again significant estimates for the spillover function. However, the coefficient for the technology field specific RDD_i is neither significant nor does show the expected sign. Consequently, for electronics these fields seem to have no significant influence on the structural development.

For the equations of table 4 again the Cox-statistics can be computed in order to evaluate whether the linear (E3) or the non-linear (E5) version of the model provied for a better fit. Here the results are quite similar to the one found in table 3, at least for machinery. Here neither formulation is dominant again. For electronics, however, the non-linear equations are clearly superior.

Summarizing these different estimations we find that concerning the technology gap structure spillover effects seem to be relevant for the relative performance of firms. However, there are significant differences between the two sectors under consideration. For electronics spillover effects tend to be more relevant than in machinery. This seems to be quite compatible to the sector classification provided by Pavitt (1984). There machinery is described as a specialized supplier where technological progress mainly comes from the relation to customers. Own R&D activities and the bounding effect of the technology fields indicate that it is the specialized nature which determines further advances. Thus, firm strategies seem to focus more on diversification and finding technological niches where the threat of competition is less severe. A rather horizontal industry structure is the result.

Electronics, contrariwise, is technologically more homogeneous because firms rely on quite similar technological, science-based sources. Thus, firms seem to rely also on the screening of the advances of their competitors. Within this strong vertical industry structure competition is characterized by innovation-imitation resulting in siginficant spillover effects.

4. Conclusion

The analysis we present in this paper is concemed with the technological dynamics within economic sectors. A simple model of the technological interaction between best-practice and below best-practice firms is used to identify the mechanism of catching-up and falling-behind. Here the spillover effects and the absorptive capacity of firms are of major importance. For empirical test of the specific mechanism of the model data for firms from the German electronics and machinery sector are used respectively. We can show that the model's mechanism seems to be relevant for a technologically determined structural change in these sectors. The respective results, however, differ nevertheless considerably. For electronics the important role of spillovers and absorptive capacities show up significant which seems to indicate that research there relies to a considerable degree on screening the activities of competitors (here the best-practice firms). In machinery this spillover effect is less important. The own R&D activities and the rather specialized development within certain technology fields seem to be the dominating factors for structural changes. Finally, for any Interpretation one has to take into account that the structural change in electronics is much higher than in machinery.

The results obtained so far indicate that technological progress seems to be an important factor determining strutural change within economic sectors. To improve the results found so far the model above obviously has to be enhanced by the following: (1) In the theoretical model as well as in the econometric analysis economic factors such as market shares have to be given more weight. (2) For the various variables included in the regression analysis better or additional proxies should be found - such as R&D for basic research, technological sophistication of Investment, etc. (3) The number of sector to be investigated has to be increased - only then it would be possible to identify clear-cut sectoral specifities. All this is on the agenda for future work.

References:

Abramovitz M. (1988), *Thinking about Growth*, Stanford: Standford University Press, 1988.

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

Cantner U., H. Hanusch, G. Westermann (1996), Detecting Technological Performance and Variety - An Empirical Approach to Technological Efficiency and Dynamics, forthcoming in: Helmstädter E., M. Perlman, *Economic Dynamism: Analysis and Policy.*

Cantner U., A. Pyka (1995), Absorptive Capacity and Technological Spillovers, University of Augsburg, mimeo (Absorptive Fähigkeiten und Technologische Spillovers - Eine Evolutionstheoretische Simulationsanalyse, Institut für Volkswirtschaftslehre, Universität Augsburg, Volkswirtschaftliche Diskussionsreihe, #133, 1995).

Cantner U., G. Westermann (1995a), Localized Technological Progress and Industry Structure - An Empirical Approach, *Journal of New Technology and Innovation*, forthcoming.

Cantner U., G. Westermann (1995b), Factor Prices, Technological Trajectories and Firm Asymmetries, paper presented at the EAEPE-Conference, Krakau, October 20-22, 1995.

Cohen W., D. Levinthal (1989), Innovation and Learning: The Two Faces of R&D, *Economic Journal* 99, 1989, 583.

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

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

Greene W.H. (1993), *Econometric Analysis*, (2nd ed.), Engelwood Cliffs, NJ: Prentice Hall, 1993.

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

Pavitt K. (1984), Sectoral Patterns of Technical Change: Towards a Taxonomy and a Theory, *Research Policy* 13, 1984.

Pesaran M.H., A.S. Deaton (1978), Testing Non-Nested Nonlinear Regression Models, *Econometrica* 46, 1978, 677-694.

Simon H. (1978), Rational Decision Making in Business Organizations, *American Economic Review* 69, 493.

Verspagen B. (1992), *Uneven Growth between Interdependent Economies*, Maastricht 1992.

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