# 10 Innovation in manufacturing industry - an East West comparison*

*Michael Fritsch, Grit Franke* and *Christian Schwirten*

## 1. Introduction

The East German economy fell into deep crisis after the unification because of the following process of transformation which created inordinate pressure for innovation in the region (Brezinski and Fritsch, 1995; Fritsch and Mallok, 1998). The East German firms were faced with the necessity for drastic improvement of production processes and for a more or less complete change of their product program in order to find new markets. Eastern Germany will remain an underdeveloped region for decades unless these innovations are not successfully implemented.

This contribution analyzes differences and similarities between East and West German firms in the manufacturing industry. The interregional comparison is based on data gathered by postal questionnaires of manufacturers in one East German and two West German regions. First we will introduce the data and the three regions (Section 2). Section 3 gives information about the characteristics of the firms in the different regions and in particular outlines the economic situation of the firms. Based on these results we will then compare indicators for innovation input (Section 4) with indicators for innovation output (Section 5). Section 6 presents results of multivariate analyses of the determinants for innovation output and innovation productivity. Finally we draw a number of conclusions (Section 7).

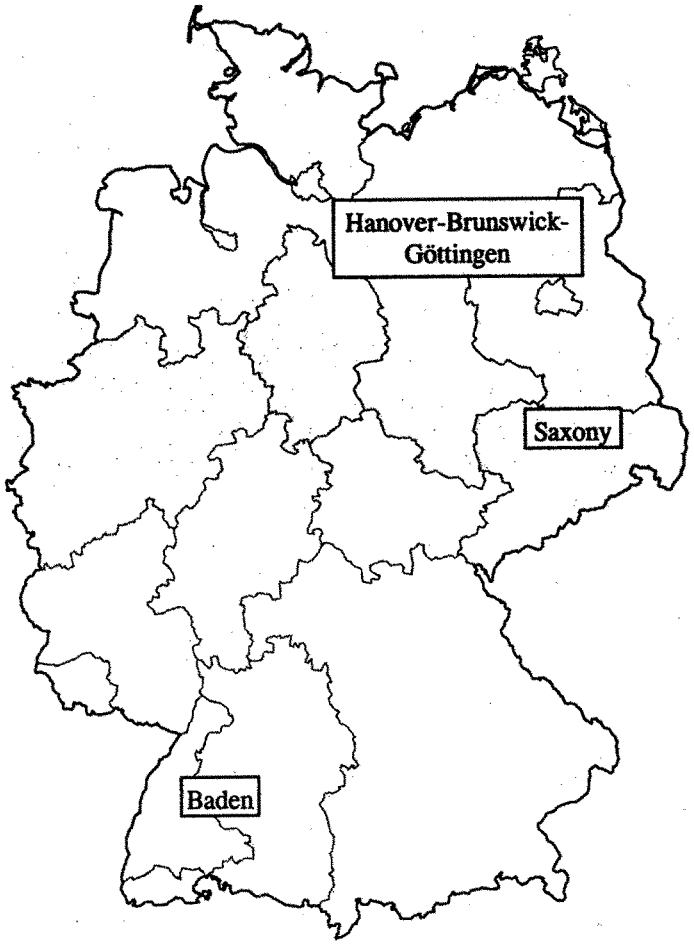
## 2. The data

This analysis is based on data gathered by postal questionnaires from manufacturing enterprises in the fall of 1995 in three German regions. The regions were (see Figure10.1):

* The work presented here is based on a research project funded by the German Science Foundation. For a more detailed description of the results for the region of Saxony see Fritsch, Bröskamp and Schwirten (1996). The research was designed as a joint project with four teams involved. The research institutions and the respective project leaders are: Department of Economic Geography at the University of Hanover (Prof. Ludwig Schätzl), Department of Economic and Social Geography at the University of Cologne (Prof. Rolf Sternberg), Fraunhofer Institute of System Analysis and Innovation Research in Karlsruhe (Dr. Knut Koschatzky, Prof. Frieder Meyer-Krahmer) and the Faculty of Economics and Business Administration at the Technical University Bergakademie Freiberg, Research Unit Innovation Economics (Prof. Michael Fritsch).

- *Baden.* This region is characterized by small and medium-sized businesses and is said to have a well functioning innovation system (particularly an efficient transfer of technology and a highly cooperative relationship among the relevant institutions).
- The region *Hanover-Brunswick-Göttingen* is identified by a high proportion of large scale enterprises and a strong dependency on the automobile industry. Despite considerable efforts by the regional government the innovation rate in this region is below average (Schasse, 1995).
- *Saxony* is an East German region with a long industrial tradition. Saxony is expected to grow faster than the other East German regions.

*Figure 10.1 Case study areas*




Altogether the survey yielded about 1 800 useful responses. Since the focus of the questions was on innovation the data was checked for innovation bias as one could expect a relatively low representation of non-innovative enterprises.[1] Of the Saxon firms who

1 In all three regions addresses of the firms were made available by the member lists of the German Chambers of Industry and Commerce. In this survey we selected firms which were in the manufacturing industry, registered in the Commercial Register, and had more than 10 employees according to the member

originally did not respond, we asked a sample of 100 for important indicators like firm size, amount of employees in R&D, and development of innovation. The non-response analysis revealed that there is no such innovation bias.[2] The data of the questionnaires in Baden was compared with indicators from other questionnaires for this region. There were no significant differences in the indicators between the different questionnaires (Koschatzky, 1997). For these reasons, the danger of strong bias in the data can be assumed to be very low.[3]

## 3. Characteristics of the firms

Table 10.1 shows the average number of employees, average turnover, and a sample of further indicators to describe the different situations of firms in the three regions. We not only find significant differences between East and West Germany but also between the two West German regions with regard to these indicators. Therefore, we shall distinguish between East (Saxony) and West Germany and also between the two West German regions Hanover and Baden.

The East German firms in the sample are - measured by their median number of employees in 1995 - smaller than their West German counterparts. 50 percent of Saxon firms employ 35 or less people on average compared to 70 employees in firms in Hanover. The median number of employees in Baden amounts to 37.5 and is quite close to average firm size in Saxony. The prevalence of small and medium size enterprises in Saxony can be put down to two facts:

- Firms which had been established before 1989 have had to reduce employee numbers because of the economic situation following unification (Brezinski and Fritsch, 1995; Fritsch and Mallok, 1998). In our sample, employment in East German firms decreased by 28 percent in the 1992-95 period.
- New firms usually start small. Therefore, firms established after unification have a relatively low number of employees.[4]

The proportion of employees with a significant higher level of education (tertiary) in Saxon firms indicates a higher level of formal education in these firms and thus a higher stock of human capital. In the interpretation of these results we have to consider that the

---

list of the CIC. The response rate for the questionnaires amounted to 21.8. For more information on the sample, response rates and some analyses based on this data set see Fritsch, Bröskamp and Schwirten (1996), Backhaus and Seidel (1997) or Koschatzky (1997).

2 However, the share of R&D employees in firms with R&D personnel in our sample was a little higher than in innovative firms which did not participate in the survey.

3 If such a bias does exist, it would be present in the sample for all three regions because of the similar design of the questionnaires. A comparison between the regions therefore would not be affected.

4 This proportion of firms in Saxony did not decrease their employment stock. They increased their workforce by about 60.5 percent between 1992 and 1995.

formal educational degrees of East German employees can not always be regarded as equivalent to the West German educational degrees.[5]

*Table 10.1 Indicators for the firms' number of employees, turnover and profits, differentiated by regions*

| | Saxony | West Germany | Hanover | Baden |
|---|---|---|---|---|
| Number of employees per firm in 1995 (median)[a] | 35.0 | 50.0** | 70.0** | 37.5** |
| Employment trend 1992-1995 (in percent; mean)[a] | 27.8 | 7.4** | 7.4** | 7.4** |
| Proportion of employees with tertiary degree (university) in 1995 in percent (median)[a] | 12.9 | 6.3** | 6.3** | 6.3** |
| Ratio of value added to turnover[c] 1994 (median)[a] | 56.0 | 62.7** | 61.5** | 65.0** |
| Gross added value by manufacturing [d] per employee in 1994 per thousand DM (median)[a] | 61.7 | 109.1** | 114.0** | 104.3** |
| Unit labor costs in 1994[e] (in percent, median)[a] | 58.7 | 53.4** | 51.9** | 55.2** |
| Gross profit[f] per employee in 1994 in thousand DM (median)[a] | 26.7 | 49.4** | 52.6** | 45.3** |
| Ratio of turnover inside the region to the total amount of turnover (in percent) in 1994, (mean)[a] | 24.9 | 20.4** | 20.3** | 20.8** |
| Proportion of firms exporting (in percent) in 1994[b] | 47.6 | 69.8** | 70.0** | 69.7** |
| Ratio of export turnover to total amount of turnover (propensity to export in percent, mean; firms with export only)[a] | 26.8 | 35.3** | 35.9** | 32.5** |

*Notes:* ** Significant difference compared to Saxony at the 1-percent level; a Mann-Whitney-tests; b Chi square-tests; c Ratio of gross added value (turnover minus expenditures for raw materials, factory and supplies) to turnover; d Turnover minus expenditures for raw materials, factory and supplies; e Ratio of expenditures for wages and salaries to gross added value; f Turnover minus expenditures for raw materials, factory and supplies and minus expenditures for wages and salaries.

The ratio of (gross) value added to turnover describes the extent of the vertical range of manufacture. With just 56 percent the share of value added to turnover in Saxon firms is rather small when compared to the West German counterparts.[6] The gross added value per employee represents an indicator for labor productivity. The low value of this indicator in Saxony (61 700 DM compared to 109 000 DM in the West German regions) implies a falling behind of the productivity of the West German regions (for further

5 For example, a period of training for a skilled worker in the GDR was about two years, compared with three years in West Germany (for more detailed explanations see Wagner, 1993). For differences in the qualification patterns between East and West German firms see Mallok (1996).

6 For causes of lower vertical range of manufacture of East German firms see Fritsch and Mallok (1998).

implications see Fritsch and Mallok, 1998). Apparently the process innovations in the East German firms have not been sufficient to close the productivity gap. The low productivity in the East German firms and the increasing parity of wages between the East and West German regions had led to greater pressure on the unit labor costs of East German firms. The pressure on the unit labor costs is 10 percent higher than in their West German counterparts. The gross profit (gross added value minus wage costs) per employee represents an approximation for a firm's profits. The value of this indicator (26 000 DM) is smaller than in their West German counterparts because of the lower productivity and the higher unit labor costs in Saxony.

Saxon firms focus to a higher degree on regional markets than their counterparts deriving about 25 percent of their turnover from this market.[7] Saxon firms derive altogether more than a half of their turnover (54 percent) within Eastern German regions. Furthermore, we find a low presence of East German firms on international markets as represented by the firms' propensity to export. Only 47.6 percent of the Saxon firms export, compared with 70 percent of the firms in Baden and Hanover. Furthermore, for those Saxon firms who export, the exported goods account for a much smaller proportion of the turnover compared to their West German counterparts. This suggests that East German firms are insufficiently established in national and international markets and that they are less competitive.

Altogether these indicators show Saxon manufacturers to be less efficient on average, which was the cause for a strong decline in workforce in the years prior to our survey. The results per employee in Saxony are very low because of the high unit labor costs compared to the West German regions.

## 4. Input of innovation processes

In comparing indicators for innovation inputs one has to take into account that many statistics correlate with a firm's size. Since the opportunity of a functional division of labor increases with the size of a firm, large enterprises, for example, employ R&D personnel much more often than small and medium sized firms (cf. Kleinknecht, 1987). In Hanover 78 percent of all enterprises had R&D personnel while in Saxony this proportion was only 75 percent (Table 2). This result is probably due to the fact that in Hanover companies are on average larger than in Saxony (Table 10.1). However, a comparison with Baden indicates that other factors than size play a role, too. In Baden, only 70 percent of all firms employ R&D staff, though firms in Baden are slightly larger than their counterparts in Saxony. The situation looks different when the ratio of R&D

7 In Baden the focus on this region regarding the turnover is lower than in Table 10.1 because of the different definitions of 'region' in the three parts of the questionnaires. The definition of the region in Saxony and in Hanover were the state Saxony and the region Hanover-Brunswick-Göttingen. These two regions have nearly the same size measured by the total population. In the case of Baden the 'region' as defined in the respective question was the state Baden-Württemberg. This region is much larger than Saxony or Hanover-Brunswick-Göttingen. Because of that the focus of firms on the regions is in this sample too high.

personnel to total employment is analyzed. In 1995, the R&D staff accounted for 3.7 percent in Hanover, for 5.9 percent in Saxony, and as much as 6.6 percent in Baden. Companies in Baden have the largest share of R&D staff although they employ R&D personnel least frequently.

*Table 10.2 Indicator for the input of the innovation process in East and West German manufacturing industries (percentages)*

| | Saxony | West Germany | Hanover | Baden |
|---|---|---|---|---|
| Proportion of firms with R&D employees in 1995[b] | 74.9 | 73.7 | 77.7 | 70.2 |
| Proportion of R&D employees in 1995 (all enterprises)[a] | 5.9 | 4.6** | 3.7** | 6.6** |
| Proportion of R&D employees in 1992 (all enterprises)[a] | 4.3 | 4.1** | 3.3** | 5.7** |
| Ratio of employees in research to all R&D employees in 1995 (all enterprises)[a] | 17.6 | 19.6 | 24.2 | 15.10.<br>0 |
| Changes in R&D employment between 1992 and 1995 (all enterprises) | 9.6 | 4.3 | 7.6 | 0.4 |
| Proportion of R&D expenditures to gross added value in 1994 (innovative enterprises only)[a] | 15.6 | 11.3** | 10.7** | 12.6** |
| Proportion of R&D subsequent expenditures to gross added value in 1994 (innovative enterprises only)[a] | 13.0 | 7.5** | 7.8** | 6.9** |
| R&D expenditure per employee in 1995 (median, DM, innovative enterprises only)[a] | 6 370 | 8 380** | 7 650 | 9 020** |
| R&D subsequent expenditures per employee in 1995 (median, DM, innovative enterprises only)[a] | 3 810 | 3 330 | 2 750** | 4 220 |
| Proportion of firms which cooperated with public research institutions (all enterprises)[b] | 35.9 | 31.1* | 31.2 | 31.1 |

*Notes:* ** Significant difference compared to Saxony at the 1-percent level; * Significant difference compared to Saxony at the 5-percent level; a Mann-Whitney-Tests; b Chi-Square-Tests.

For a more detailed analysis of the innovation process, the firms were asked to assign their R&D personnel to research activities and development activities respectively.[8] In Hanover 24.2 percent of all R&D staff were devoted to research activities compared to 15.1 percent in Baden and 17.6 percent in Saxony. Between 1992 and 1995 the share of R&D personnel of all employment rose in Saxony from 4.3 percent to 5.9 percent. In

8 Research was defined as 'original investigation undertaken in order to acquire new knowledge'. Development was defined as 'systematic work, drawing on existing knowledge gained from research and practical experience, that is directed to producing new or substantially improved materials, products, devices and services'.

Baden and Hanover this proportion increased, too. Yet, in Hanover this was not an increase in absolute terms. In Saxony, between 1992 and 1995 the absolute number of R&D staff went down by 9.6 percent. However, the decrease in total employment (minus 28 percent) was much larger (Table 10.1). Therefore, the proportion of R&D staff rose in Saxony. Obviously, firms in Saxony tried to improve their productivity by cutbacks in staff. At the same time they made an effort to spare R&D activities from cutbacks, activities which are crucial for the development of competitive products and for sustainable market success. Baden was the only region in which not only the proportion of R&D staff but also the absolute number of R&D personnel rose, even though this was only a modest rise of 0.4 percent.

The data concerning the R&D expenditures and the R&D subsequent expenditure clearly show that firms in Saxony invested to a considerable amount in their knowledge base.[9] It has to be taken into account that these expenditures include labor costs which in East Germany are still significantly lower than in the west. Firms in Saxony spent a much higher share of gross value on innovation than their west German counterparts. The share of R&D expenditure and R&D subsequent expenditure amounts to 15.6 percent and 13.0 percent respectively. However, the results look different,when the expenditure per employee is compared. The R&D expenditure per employee is lowest in Saxony and, it only has a midrange position for expenditure. The difference between the R&D expenditure compared to the value added and the number of employees, respectively, is largely due to the low gross value added per employee in Saxony (Table 10.1).

A relatively large proportion of all firms in Saxony (36 percent) collaborate with at least one publicly funded research institution. Multivariate analyses investigated the individual influence of various aspects such as R&D intensity and size of the firms on a company's propensity to cooperate. Even after controlling for these aspects, Saxon companies still collaborate more often with research institutions than firms in Baden and Hanover (cf. Fritsch and Lukas, 1999). This outcome is slightly surprising. One might have expected that the reorganization of the public research sector after 1989 was rather an obstacle for cooperation. However, three factors could help explain the comparatively high degree of cooperation: First, many former employees of the universities and the Academy of Sciences who are now working for industrial companies may still have many personal contacts with their former colleagues in the academia. Secondly, the innovation system of the GDR had a strong orientation towards the practical application of research results. Thus even in the pure scientific research a strong focus on industrial applicability was quite common (cf. Gläser and Meske, 1996). This could be one reason why the gap between publicly funded and industrial research in Eastern Germany is still relatively small. Thirdly, for east German enterprises a large number of special development

9 R&D expenditure was defined as 'expenditure for research, development, construction and design'. R&D subsequent expenditures were 'expenditures for the preparation of the production and the market introduction that accrue in addition to the R&D expenditures'. All data for the R&D expenditures and the R&D subsequent expenditures show the annual average for the preceding three years. This period spans the end of 1993 to the end of 1995. For reasons of simplicity we will refer to this period as 'from 1993 to 1995'.

programs for industrial firms exist. These programs to some extent also promote and subsidize the collaboration with universities and non-university research institutions.

Our results indicate that companies in Saxony made a large effort to extend their knowledge base. Many innovation input indicators rank Saxony comparatively highly. This indicates that the overall development appears to be promising. We cannot find evidence to support the assertion that East German companies are merely 'extended workbenches' of West German firms, i.e. firms with a low level of research activities that are responsible only for less sophisticated sections of the production process. This holds even for those companies mainly owned by western enterprises. We could not find evidence for significant differences regarding the innovation input between firms with western or eastern ownership.

## 5. Success of innovation

After 1989, East German firms faced enormous pressure to innovate (cf. Brezinski and Fritsch, 1995; Fritsch and Mallok, 1998). Traditional markets broke down, old machinery needed to be replaced and at the same time competitors from the West entered the markets which meant that East German firms had to make changes to the product program. Therefore it is not surprising that in Saxony a higher proportion of firms reported innovation activities between 1992 and 1995 than in Baden and Hanover (Table 10.3). About 80 percent of all firms in Saxony reported either some kind of product or process innovation.[10] Only 4.2 percent of all innovating firms in Saxony limited their innovation activities exclusively to process innovations; in Hannover and Baden this proportion was 5.5 percent and 7.2 percent, respectively.

In Saxony the proportion of the firms that reported product differentiation (84 percent) was higher than the proportion of innovating enterprises (Table 10.3).[11] This reflects the strong need of the East German manufacturing firms to update their products. Product differentiation was much less frequently mentioned by companies in the West. Those companies that reported neither innovations nor product differentiation can be regarded as the least innovative firms. In Saxony, only 5.5 percent of all respondents belonged to this category. In Baden and Hanover this proportion is about three times as high. Regarding the number of products that had been introduced or substantially improved between 1993 and 1995, no significant East-West difference could be observed. Apparently, this is due to size, since the share of new products to the total number of products is more than twice as great in Saxony than in the West.

---

10 A product innovation was defined as a substantial improvement of a product (for example with regard to the performance level, the product image and design or the usage of new components) or the production of a product that is new for the respective firm, though not necessarily new for the whole market. A process innovation was defined as a substantially improved or an entirely new production method (for example a reorganization of the production or the deployment of new machinery and production devices).

11 A product differentiation was considered an 'optical or minor technical alteration of a product without a substantial change regarding a product's performance, costs, characteristics or its components'.

*Table 10.3 Indicators for results of the innovation process in the East and West German manufacturing industry*

| | Saxony | West Germany | Hanover | Baden |
|---|---|---|---|---|
| Proportion of innovative firms in the period between 1993 and 1995 (in percent)[a] | 79.2 | 74.8 | 78.2 | 71.8** |
| Proportion of firms' product differentiation in the period between 1993 and 1995 (in percent)[a] | 84.0 | 62.1** | 63.3** | 61.0** |
| Proportion of firms without innovations and without product differentiation (in percent)[a] | 5.5 | 18.4** | 17.5** | 19.2 |
| Number of new products per enterprise in 1995 (mean, innovative enterprises only)[b] | 41.1 | 38.4 | 31.7 | 44.1 |
| Ratio of new products to total number of products in 1995 (percentage, median; innovative enterprises only)[b] | 50.0 | 23.0** | 20.0** | 25.0** |
| Proportion of turnover with new products in 1994 (percentage, median; innovative enterprises only)[b] | 40.0 | 25.0** | 20.0** | 30.0** |
| Proportion of firms with a patent in the period between 1993 and 1995 (percentage; all enterprises)[a] | 19.9 | 34.4** | 37.7** | 31.6** |
| Patents per firm (mean; enterprises with patents only)[b] | 3.8 | 7.5** | 6.9** | 8.0** |

*Notes:* ** Significant difference compared to Saxony at the 1-percent level; a Chi-Square-Tests; b Mann-Whitney-Tests.

In Saxony new or substantially improved products accounted for 40 percent of the sales of the innovating firms (Table 10.3). In Baden and Hanover this proportion was only 20 percent and 30 percent, respectively. This result is hardly surprising regarding the pressure to innovate in the East German industry. However, it seems that the full potential of the new products has not yet been fully exploited. In Baden and Hanover the share of turnover with new products equals at least the share of new products to the total number of products. At the same time, in Saxony new products contribute disproportionally little to the turnover. Apparently, manufacturing firms in Saxony still have problems with the marketing of their product innovations.[12]

Patents have a special position within the innovation process (cf. Acs and Audretsch, 1989; Griliches, 1990). On the one hand, they are a throughput of the innovation process since they represent knowledge that is being used by firms within the innovation process. On the other hand, patents can be the result of an innovation process. In this case the patenting is not followed by further innovation activities, but rather will be marketed as

12 This corresponds with the results of several other studies. Lay, Michler, Gagel and Dreher (1996, 26) found that in the East German industry the proportion of sales and marketing personnel is much smaller than in West Germany. Gergs and Pohlmann (1996) conducted a number of case studies and concluded that East German managers are often too 'technicistic', that is they neglect the needs of the demand side and ignore the necessity to exploit potential markets.

a 'product'. Both possibilities are not exclusive categories, since a patent can simultaneously be used by the firm itself and licensed to other firms.

Like other innovation indicators, patent indicators are often related to the size of the patenting firm. Large companies patent more often than smaller firms. This can be largely explained by the higher 'activity level' of bigger firms. Large firms usually employ more R&D personnel which can develop patentable ideas and likewise conduct research in a number of different technological areas. If one assumes a certain probability for the generation of a patentable idea per R&D personnel or per R&D project, then the likelihood of a patent application will rise in relation to the firm's size. The number of patents per employee or per R&D employee indicates the patent productivity and can be interpreted as a measure for the R&D efficiency (Table 10.4).[13]

As Table 10.3 shows, between 1993 and 1995 only 20 percent of all firms in Saxony applied for a patent. This can not be explained simply by the small size of these firms, since in Baden the enterprises are of a comparable size. Yet, in this region 32 percent of all firms applied for a patent. Not only do patent applications occur less frequently among firms in Saxony, but here with 3.8 patents, the number of patents per applying firm is also much smaller than in Baden and Hanover.

Table 10.4 shows several indicators that relate innovation inputs and outputs and which are therefore able to indicate the productivity of the innovation process. Concerning both the number of new products per employee and per R&D employee respectively - firms in Saxony rank between their counterparts in Baden and Hanover. The backwardness regarding the market exploitation is largely responsible for the low gross profit with new products per R&D employee in Saxony.[14] This low value relies primarily on the comparatively small gross profit of firms in Saxony (cf. Table 10.1). The gross profit with new products per R&D expenditure can be interpreted as a kind of 'return' to R&D investment. In Saxony this relationship is the highest (1.4), yet this is mainly because here the R&D expenditure per new product is rather small. Regarding the patent productivity (patents per employee / patents per R&D employee) Saxony ranks in the middle position between the two West German regions. This is similar to the results concerning the number of new products per (R&D) employee.

---

13 Several empirical studies demonstrate that this patent productivity is high in small firms and declines with size (cf. Acs and Audretsch 1990 and especially Cohen and Klepper 1996a, 1996b). However, the small number of patents per employee in large enterprises doesn't necessarily indicate a low R&D productivity. Cohen and Klepper (1996a, 1996b) explain this negative size effect as follows: Large enterprises are particularly able to exploit innovations, especially process innovations. Therefore, they do not need to generate as many patentable ideas per employee as small firms. In Cohen's and Klepper's opinion, due to the high profitability of each innovation large enterprises carry out different kind of innovation and particularly more cost intensive projects than smaller firms. According to this view the small number of innovations per employee which can be observed in large firms should be interpreted as a result of certain economic considerations rather than a sign of low productivity.

14 The 'gross profit with new products' has been calculated as 'gross profit' multiplied by the proportion of new products. Implicitly this method assumes that the turnover's proportion of the gross value added (vertical range of manufacture) is identical for old and new products.

*Table 10.4 Indicators for productivity of the innovation process*

| | Saxony | West Germany | Hanover | Baden |
|---|---|---|---|---|
| Number of new products per employee in 1995 (mean, innovative enterprises only)[a] | 0.55 | 0.29** | 0.12** | 0.64* |
| Number of new products per R&D employee in 1995 (mean, innovative enterprises only)[a] | 9.3 | 5.5 | 2.8* | 8.8 |
| Gross profit per firm with new products per R&D employee in thousand DM (median; innovative enterprises only)[a] | 138 | 235** | 261** | 220** |
| Gross profit per firm with new products per R&D expenditures (median; innovative enterprises only)[a] | 1.4 | 1.2 | 1.3 | 1.1 |
| Patents per employee (mean; enterprises with patents only)[a] | 0.029 | 0.023** | 0.017** | 0.03** |
| Patents per R&D employee (mean; enterprises with patents only)[a] | 0.39 | 0.38** | 0.35** | 0.41** |

*Notes:* ** Significant difference compared to Saxony at the 1-percent level; * Significant difference compared to Saxony at the 5-percent level; a Mann-Whitney Tests.

## 6. Multivariate analyses of the innovation success

Based on bivariate analyses, in Sections 3 to 5 we were able to identify several differences between the firms in Saxony and those in West Germany. However, a proper assessment of the East German firms' innovation activities and innovation success requires multivariate analyses that control simultaneously different aspects such as size of the firm, the region under investigation or the industrial sector.[15] The following indicators regarding the innovation activities were included as dependent variables in our analysis:

- *Implementation of innovations:* This variable assumes the value 1 for all firms that reported some innovation during the three years preceding our survey. The variable is 0 for firms without innovation.
- *Product differentiation*: For firms that modified their products during the survey period, the variable is 1. Otherwise it is 0.
- *Number of new products*: Number of products that had been newly developed or substantially improved during the three years preceding the survey. In order to

15 In Saxony the industrial firms are relatively small compared to Baden and Hanover. Therefore, many differences between these three regions could be caused by different structures in firm size. In a similar way, this also applies to other potentially relevant aspects like the regional industrial structure or the regional R&D intensity. Thus, the influence of a firm's location can only be identified by multivariate analysis.

diminish the influence of extreme values the number of products is a grouped variable.[16]

- *Proportion of new products*: Proportion of the new or substantially improved products to total number of products. This indicator describes the innovativeness of a firm's product program.
- *Proportion of turnover with new products*: Proportion of the turnover of the new or substantially improved products. This indicates how successful the new products are in the marketplace.
- *Patent activity*: This variable is 1 if the enterprise applied for a patent during the study period and 0 otherwise.

Two further variables capture the innovation productivity:

- *New products per employee*: Number of new products per employee in 1995.
- *Patents per employee*: Number of patents pending between 1992 and 1995.

The independent variables are as follows: the number of employees,[17] the R&D intensity (share of R&D personnel),[18] a dummy variable for the region where a firm is located,[19] the industrial sector,[20] and two further dummy variables which refer to research activities and development activities, respectively. This variable is 1 if these activities are conducted permanently and 0 otherwise.

Table 10.5 shows the multivariate statistics regarding the innovation activities. In all estimations, except for the share of new products and new product turnover, a positive and significant influence of a firm's size can be noted. This is in accordance with our expectation that larger firms are more likely to innovate or to modify their products, patent more often and usually have a larger number of products. The R&D intensity (share of R&D personnel) and/or the dummy variable for the frequency of development activities positively influenced all indicators concerning innovation success. In addition continuity of research is also an influential factor for patenting.

---

16 The groups are: no new products = 0; one to five new products = 1; six to ten new products = 2; eleven to 20 new products = 3; more than 20 new products = 4.

17 For this variable the logarithm of the number of employees has been used in order to approximate the distribution of this value to the normal distribution.

18 The data for the total employment and the R&D employment refer to 1992, which is the beginning of the period studied. This ensures that the number of R&D employees and the R&D intensity can be interpreted as the cause of the innovation activities. Estimations with data for 1995, however, do not show significantly different results.

19 This dummy variable represents the influence of a location in Baden and Hanover, respectively. The firms in Saxony form the control group.

20 The firms were aggregated into seven groups. Each group comprised several two-digit sectors of the German SIC. The sector 'electronics/business machines' was used as a control group.

*Table 10.5 Results of the multivariate analysis*

| | Implementation of innovations[a] | Product differentiation[a] | Number of new products (grouped)[b] | Proportion of new products[c] | Proportion of turnover with new products[c] | Patent activity (patents yes/no)[a] | Number of patents per firm[d] |
|---|---|---|---|---|---|---|---|
| | | | *Independent variables* | | | | |
| Number of employees in 1992 (ln) | 0.20** (4.61) | 0.13** (3.46) | 0.09** (2.78) | 0.001 (0.04) | -0.03 (1.01) | 0.28** (8.01) | 0.68 (46.22) |
| Proportion of R&D employees in 1992 | 0.02** (3.18) | 0.01 (1.14) | -0.001 (0.50) | 0.20** (5.42) | 0.07* (2.12) | 0.02** (4.13) | 0.03 (17.83) |
| Dummy variable for continuous research | 0.27 (1.32) | -0.07 (0.53) | 0.03 (0.31) | -0.03 (0.93) | 0.05 (1.64) | 0.32** (2.94) | 0.45** (9.76) |
| Dummy variable for continuous development | 1.27** (10.92) | 0.75** (7.39) | 0.47** (5.12) | 0.06 (1.74) | 0.16** (4.61) | 0.60** (6.07) | 1.44** (15.76) |
| Dummy variable for the location Baden | -0.42** (3.89) | -0.80** (7.44) | 0.05 (0.52) | -0.18** (4.99) | -0.17** (5.29) | 0.43* (4.23) | 1.04** (18.47) |
| Dummy variable for the location Hanover | -0.37** (3.06) | -0.86** (7.55) | -0.11 (0.27) | -0.23** (6.41) | -0.22** (6.72) | 0.34** (3.28) | 0.27** (4.38) |
| | | | *Industry dummy variables* | | | | |
| Food, beverages and tobacco | -0.36 (1.61) | -0.15 (0.70) | -0.16 (0.92) | -0.03 (0.69) | -0.16** (4.40) | -0.98** (4.19) | -1.07** (6.32) |
| Textiles, clothing, leather | -0.59** (2.63) | -0.06 (0.97) | 0.31 (1.80) | 0.14* (3.64) | 0.06 (1.57) | -1.24** (5.38) | -2.24 (7.93) |
| Wood, furniture, paper, printing, publishing | -0.32 (1.77) | -0.16 (0.97) | -0.09 (0.68) | 0.07 (1.58) | -0.03 (0.84) | -0.52** (3.43) | -0.26** (3.28) |
| Mineral oil, chemicals, rubber, plastics, stone, ceramics, glass | -0.40* (2.17) | -0.16 (1.0) | 0.21 (1.56) | -0.06 (1.32) | -0.10* (2.51) | -0.05 (0.35) | 0.34** (5.21) |
| Metal products, recycling | -0.40* (2.25) | -0.34* (2.21) | 0.11 (0.79) | -0.04 (0.92) | -0.03 (0.73) | -0.42** (2.92) | -0.47** (4.86) |
| Mechanical engineering, vehicles | -0.13 (0.69) | -0.06 (0.39) | -0.27* (2.24) | 0.05 (1.23) | -0.02 (0.50) | -0.02 (0.17) | 0.11 (1.95) |
| Number of cases | 1 362 | 1 140 | 872 | 825 | 915 | 1 322 | 1 322 |
| $R^{2adj}$ | 0.28 | 0.16 | 0.03 | 0.13[f] | 0.14[f] | 0.23 | 0.53 |

*Notes:* a Estimated probit coefficients, asymptotic t values in parentheses, b Ordered probit regression, coefficients, asymptotic t values in parentheses, c OLS, beta-coefficients, asymptotic t values in parentheses, d Poisson regression, coefficients, asymptotic t values in parentheses, e Pseudo $R^2$, f $R^{2adj}$, ** Significant at the 1-percent level, * Significant at the 5-percent level.

The location dummy variables are significant and positive in the estimations concerning patenting. This indicates a lower level of innovative activities in terms of patents in Saxony. For most of the other indicators, though, the location dummy variables were negative. Here firms in Saxony appear to be more innovative than enterprises in Baden and Hanover. At first these results might look contradictory. But

one needs to take into account that the various indicators (patents, innovations) represent different parts of the innovation process. In our survey a broad definition of 'new products' was used to include all products that were new from a firm's viewpoint, and this included imitation.

*Table 10.6 Results of multivariate analyses for productivity indicators*

| | Number of new products per employee[a] | Patents per employee[a] |
|---|---|---|
| *Independent variables* | | |
| Number of employees in 1992 | -0.22** | -0.18** |
| | (5.97) | (6.05) |
| Proportion of R&D employees in 1992 | -0.04 | 0.21** |
| | (0.99) | (7.20) |
| Dummy variable for continuous research | 0.02 | 0.10** |
| | (0.47) | (3.64) |
| Dummy variable for continuous development | 0.05 | 0.13** |
| | (1.22) | (4.28) |
| Dummy variable for the location Baden | 0.03 | 0.08** |
| | (0.87) | (2.68) |
| Dummy variable for the location Hanover | -0.02 | 0.05 |
| | (0.59) | (1.86) |
| *Industry dummy variables* | | |
| Food, beverages and tobacco | -0.05 | -0.01 |
| | (1.15) | (0.46) |
| Textiles, clothing, leather | 0.03 | -0.07* |
| | (0.75) | (2.21) |
| Wood, furniture, paper, printing, publishing | -0.01 | -0.05 |
| | (0.31) | (1.39) |
| Mineral oil, chemicals, rubber, plastics, stone, ceramics, glass | 0.03 | -0.02 |
| | (0.68) | (0.43) |
| Metal products, recycling | 0.07 | -0.04 |
| | (1.64) | (1.25) |
| Mechanical engineering, vehicles | -0.03 | 0.02 |
| | (0.72) | (0.50) |
| Number of cases | 872 | 1 322 |
| $R^{2adj}$ | 0.05 | 0.14 |

*Notes:* a OLS, beta-coefficients, asymptotic t values in parentheses, ** Significant at the 1 percent level, * Significant at the 5 percent level.

However, in order to be patentable a product or device not only has to be new for the patenting firm but for the whole market. It appears that the innovations in Saxony consist of a higher degree of non-patentable products than in West Germany. This is not really surprising, since East German firms were primarily concerned with catching up with their western competitors. Thus, imitation and incremental innovation were the core strategies in the first years of the transformation. The negative influence of the industry dummy variables indicates that firms in the control group (electronics/business machines) patent comparatively frequently.

Table 10.6 contains two estimates for innovation productivity.[21] In both models, size has a negative and significant influence. This is in accordance with the results of other studies (cf. Acs and Audretsch 1990, Cohen and Klepper 1996a, 1996b). The R&D intensity and the continuity of research and development activities positively influenced the number of patents per employee. No such effect was found for the number of new products per employee. Here, the location dummy variables also had no significant influence. Yet, regarding the number of patents per employee the location dummy variable for Baden was significant and positive. The coefficient for Hanover is positive, too, but not significant. Even after controlling for size, R&D intensity and industry, firms in Saxony not only applied for patents less frequently than firms in Baden, but those firms with patents also reported a smaller number of patents per employee. A possible explanation is that until 1995 East German firms were more focused on non-patentable catch-up innovations.

Our results suggest that there are considerable differences between the innovation systems in the three regions studied. Saxony in particular stands out from the two West German regions. What is remarkable, however, is that indicators regarding the firm's assessment of the regional framework or potential innovation obstacles were not able to explain a significant proportion of the differences in innovation productivity or innovation success.[22]

## 7. Conclusions

East German manufacturing faces enormous pressure to innovate. In many respects, industrial firms in Saxony show a higher level of innovation activity than their counterparts in the West, even when controlling for effects of size and type of industry. This may be a response to market pressure, but could also be due to the extensive development programs for East German firms. Enterprises in Saxony were especially innovative with respect to the production process and the renewal or improvement of their products. However, the number of patent applications is much smaller in Saxony than in the other two regions. This suggests that the innovations in Saxony are new only for innovating firms rather than for the whole market. This focus on product imitations and incremental innovations could be explained by the particular need for East German firms to first catch up with their western competitors. Additionally, the critical economic

---

21 Estimations with alternative indicators for the innovation productivity show similar coefficients. Yet, in many cases they were not significant and only much smaller proportions of the variance could be explained by these estimations.

22 A lack of equity capital and a lack of outside capital were significantly mentioned more often in Saxony than in Baden and Hanover. Availability of R&D or production personnel as well as a lack of opportunities for cooperation with industry or research institutions was a less frequent problem in Saxony. Regarding the innovation framework, firms in Saxony significantly evaluated more positively the 'general innovation climate', the opportunities for consultation, the technological and economic development policy and the availability of qualified staff. However, the quality of transport infrastructure was rated much lower than in Baden and Hanover.

situation and a shortage of resources did not grant many firms the scope and time which are normally necessary to develop patentable innovations. Furthermore, it cannot be ruled out that the regional innovation system did not function optimally during the transition period after 1989. As far as this was the case, this certainly did not support innovation activities in industry.

However, the overall picture of our results is rather positive. Despite the critical condition in which many firms found themselves after 1989, they did not neglect research and development. Instead, they made an intensive effort, even though many innovations still show a lack of 'depth' (i.e. they are not patentable). In addition, our results suggest that East German firms are still having more difficulties with marketing their innovations than companies in Baden or Hanover. This clearly demonstrates that innovation activities alone are not enough for economic success but that complementary functions within innovating firms have to be developed, too.

## References

Acs, Zoltan J. and David B. Audretsch (1989); Patents as a measure of innovative activity; *Kyklos*, 42, 171-180.

Acs, Zoltan J. and David B. Audretsch (1990); *Innovation and Small Firms*; Cambridge MA: MIT-Press.

Backhaus, Angela and Olaf Seidel (1997); *Innovationen und Kooperationsbeziehungen von Industriebetrieben, Forschungseinrichtungen und unternehmensnahen Dienstleistern: Die Region Hannover-Braunschweig-Göttingen im interregionalen Vergleich* (Innovation and cooperative relationships of manufacturing establishments, research institutes and business related service firms in the region Hanover-Brunswick-Göttingen: An interregional comparison); Hanover: University of Hanover, Institute for Economic Geography (Hannoversche Geographische Arbeitsmaterialien Nr. 19-1997).

Brezinski, Horst and Michael Fritsch (1995); Transformation: The shocking German Way; *Moct-Most*, 5, 1-25.

Cohen, Wesley and Steven Klepper (1996a); Firm size and the nature of innovation within industries: the case of process and product R&D; *Review of Economics and Statistiscs*, 78, 232-243.

Cohen, Wesley and Steven Klepper (1996b); A reprise of size and R&D; *Economic Journal*, 106, 925-951.

Fritsch, Michael, Annette Bröskamp and Christian Schwirten (1996), *Innovationen in der sächsischen Industrie - Erste empirische Ergebnisse* (Innovation in Saxony's manufacturing - First results); Freiberg: Working Paper 96/13, Faculty of Economics and Business Administration, Technical University Bergakademie Freiberg.

Fritsch, Michael und Rolf Lukas (1999); Innovation, cooperation, and the region; in Audretsch, David B. and Roy Thurik (eds.); *Innovation, Industry Evolution and Employment*, Cambridge: Cambridge University Press, 157-181.

Fritsch, Michael and Jörn Mallok (1998), Surviving the transition: the process of adaptation of small and medium-sized firms in East Germany; in Horst Brezinski, Egon Franck and Michael Fritsch (eds.), *The Microeconomics of Transformation and Growth*, Cheltenham: Edward Elgar, 163-184.

Gergs, Hans-Joachim and Markus Pohlmann (1996); Manager und Märkte - Der 'Mechanismus' des Marktes und die Grammatiken der Marktaneignung des ostdeutschen Managements (The market 'mechanism' and the grammars of appropriating the market by East German management); in Pohlmann, Markus and Rudi Schmidt (eds.), *Management in der ostdeutschen Industrie*, Opladen: Leske + Budrich, 291-314.

Gläser, Jochen and Werner Meske (1996); *Anwendungsorientierung von Grundlagenforschung? Erfahrungen der Akademie der Wissenschaften der DDR*; Frankfurt a.M.: Campus.

Griliches, Zvi (1990); Patent statistics as economic indicators; *Journal of Economic Literature*, 28, 1661-1701.

Kleinknecht, Alfred (1987); Measuring R&D in small firms: how much are we missing?, *Journal of Industrial Economics*, 36, 253-256.

Koschatzky, Knut (1997); *Entwicklungs- und Innovationspotentiale der Industrie in Baden - Erste Ergebnisse einer Unternehmensbefragung* (Potentials for innovation and development of manufacturing industry in Baden: first results of an inquiry), Karlsruhe: Fraunhofer-Institute for System Analysis and Innovation Research (Arbeitspapiere Regionalforschung Nr. 5).

Lay, Gunter, Thomas Michler, Sabine Gagel und Martin Dreher (1996); *Produktionsstrukturen in der Investitionsgüterindustrie Sachsens - ein Vergleich mit den alten und neuen Bundesländern* (Production structures in Saxony's investment goods industries - a comparison of the old and the new states); Dresden: Sächsisches Staatministerium für Wirtschaft und Arbeit (Reihe Studien, Heft 6).

Mallok, Jörn (1996); *Engpässe in ostdeutschen Fabriken* (Bottlenecks in East German factories); Berlin: edition sigma.

Schasse, Ulrich, (1995); Produkt- und Prozeßinnovationen in Niedersachsen (Product and process innovation in Lower Saxony); in Schasse, Ulrich und Joachim Wagner (ed.), *Erfolgreich produzieren in Niedersachsen*, Hanover: Niedersächsisches Institut für Wirtschaftsforschung (NIW-Vortragsreihe, Bd. 10), 61-82.

Wagner, Karin (1993); Qualifikationsniveau in ostdeutschen Betrieben - Bestand, Bewertung, Anpassungsbedarf (Qualification levels in East German firms - stock, evaluation and need for adjustment); *Zeitschrift für Betriebswirtschaft*, 63, 129-145.