Human capital and innovation in East and West German manufacturing firms

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Abstract
The paper analyses the theoretical and empirical relationship between employment, skill structure and innovation in East and West German manufacturing firms. The econometric part builds on firm data from the Mannheim Innovation Panel 1993, 1994 and 1995. In the German industrial sector, especially in East Germany, employment has declined and the share of highly skilled labour has risen. The econometric investigation of labour demand, based on the translog production function, reveals differences in the firms' behaviour in East and West German manufacturing and between innovative and non-innovative firms. It is shown that complex patterns of substitution between capital and different types of labour emerge, which depend on the stage of economic transformation, the type of firms, wage setting behaviour and public policy. The results suggest that in the current stage of transition subsidising labour might be more effective for creating jobs in East Germany than promoting R&D and capital equipment. Subsidies can be lower the higher the workers' qualification level is.

JEL-Classification: J31, L60, O33

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1 Introduction

Technological progress has contributed to an immense rise in products, productivity and income in western economies. Technological progress was not as intensive in the socialist countries. Therefore, in the transition to a market economy, workers, firms and officials have to find their way along the road of technical knowledge. However, the pace of economic and technological change is sluggish, irrespective of whether the focus is on an economy in transition or a mature market economy. Technological progress both creates and destroys jobs. The short and long run impacts differ and occur in different industries at various skill levels.

Through the transformation process, unemployment in East Germany has risen to levels higher than in West Germany. In East German manufacturing, the simultaneous processes of job destruction and upgrading of skills are even more visible than in the West, despite that in terms of formal vocational qualification East German workers are better qualified. In East German manufacturing, the 1993 employment level was only 54% of employment in 1991. The share of workers with university degrees rose from 8.8% to 12%. In West Germany, manufacturing employment in 1993 stood at 93% of the 1991 level, while the share of workers with university degrees rose from 7.5% to 8.5%.

The inherited skill structure may be an obstacle to the transition to a market economy, since education and training had been designed for the needs of a different economic system. Since unification, training and retraining of unemployed workers (see Hübler 1994) and research and development (R&D) by firms (see König and Spielkamp 1995) have been promoted on a large scale by the German government. Officials hope that training and innovation will help the East German economy head toward full employment. However, little is known about the empirical relationship between types of innovation and their impact on employment or the relationship between innovation and the skill structure in the transformation process.[1]

The aim of this paper is to discuss these relationships from a microeconomic point of view (Chapter 2) and to compare the situation in both parts of Germany using 1995 manufacturing firm data, where innovative and non-innovative firms and five types of skilled labour can be distinguished (Chapter 3). The econometric investigation of labour demand, based on the translog production function (Chapter 4), reveals differences in the firms' behaviour in East and West German manufacturing and between innovative and non-innovative firms. The different types of skilled labour are

[1] Sinn (1995) discusses the role of wage policy and investment support in the process of transition in East Germany without distinguishing between different types of skilled labour and innovative and non-innovative firms.

substitutes, although to a different degree. The speed of skill upgrades is higher in East than in West Germany and in innovative than in non-innovative firms. To create more employment, it is necessary, but not sufficient, to train the unemployed because in Germany wages as well as labour costs are rather inflexible downward. An alternative policy for creating employment is to subsidise labour. Subsidies should be higher the lower the workers' qualification level is. The last section concludes with remarks on further research.

2 Skill structure and innovation in economic research

Up to now, a generally accepted theory of technological change and its impact on employment and the skill structure as well as the influence of human capital formation on innovation has not been developed in the literature. This chapter reviews some basic models and selected empirical work, focusing mainly on the microeconomic level.[2] Furthermore, some unsettled questions on the relationship between human capital and innovation are discussed.

2.1 Exogenous innovation, employment and skill structure

Innovation is defined as an enhancement of the set of production possibilities. Process innovation enables a good to be produced using a smaller amount of at least one input factor. When an entirely new or an improved good has been invented and sold at least once in the market, a product innovation is said to have taken place.[3] Since many firms produce more than one product and are continuously engaged in R&D, process and product innovations often occur simultaneously. Process and product innovations can have a positive as well as a negative impact on employment and the skill structure, depending on the structure of supply and demand in input and output markets. The most important economic factors determining the impact of innovation on employment and the skill structure are summarised in Figure 1. In short, the impacts will depend on the following:

- the state of current technology, which is usually described by measures of elasticity of substitution between different input factors, the degree of economies of scale and the degree of economies of scope (in the case of multiproduct firms);

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[2] See also Brouwer, Kleinknecht and Reijnen (1993), Goldwin and Katz (1996), Katsoulacos (1986), König (1996), Stoneman (1983), Stoneman and Diederen (1994). For a more extensive discussion of sector related studies see OECD (1994).

[3] A process innovation is considered radical when it enables a firm to achieve a monopoly position in the market through lower prices. Otherwise, it is termed incremental (see Tirole, 1989). Product innovations include quality improvements of existing products as well as the creation of entirely new products (radical product innovation).

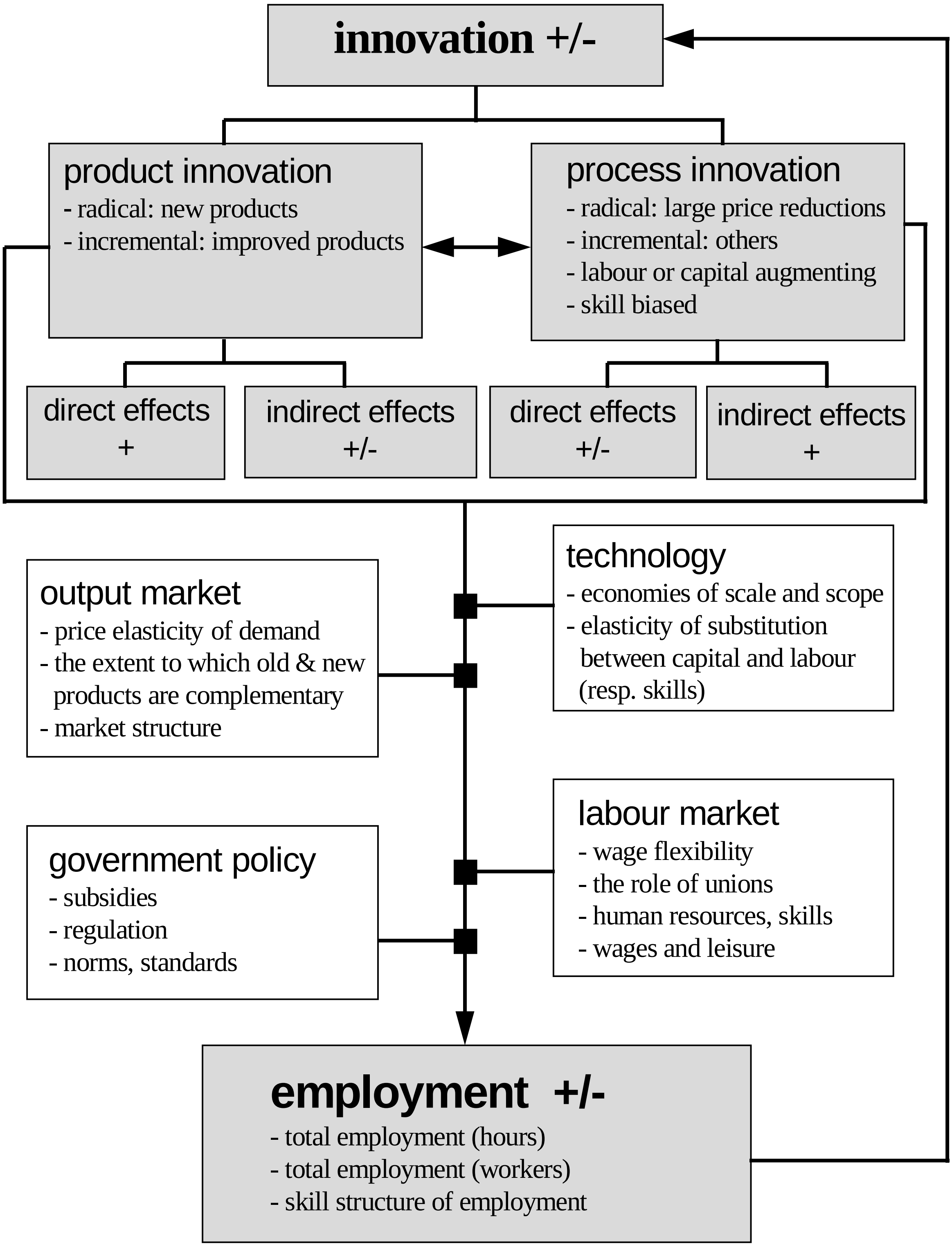
- the nature (product vs. process innovation), direction (capital or labour enhancing; skill biased or neutral) and degree of technological progress (radical vs. incremental technical changes);
- the extent, composition and dynamics of individual and aggregate demand (including the price elasticity and the degree to which new and existing products are complementary);
- the structure of product markets (degree of competition, existence of entry barriers);
- the structure of input markets and relative factor costs; especially the labour market (labour supply, wage bargaining and unions);
- the skill structure of the work force as well as the regional and occupational mobility of workers.

In the case of only one input (for example, labour) and one output, the direct impact of process innovation on employment at the firm level is zero or negative. There is an indirect effect (or compensation effect) stemming from cost reductions, which may lead to price reductions. If, as a consequence of lower prices, output rises such that the number of workers or the hours worked increases, then the positive compensation effect is larger than the direct negative effect. In the framework of perfect competition and disregarding wage changes, this occurs when the absolute value of the price elasticity of demand is greater than one.

In the case of two inputs, capital and labour, technological progress can relate to each individual input or both. Progress is termed labour- or capital-saving when the same output can be achieved with fewer workers or capital, respectively.[4] If capital becomes more productive, fewer workers will be needed to achieve a given output (direct or substitution effect). Indirect or compensation effects can again arise from lower costs. If labour becomes more productive, then labour will presumably be substituted for capital. The net impacts will depend on the state of technology, that is, on the question whether and to what extend inputs are substitutes or complements.

[4] For the further division into Hicks-, Harrod- and Sollow forms of technological progress see Neary (1981) and Stoneman (1983).

Figure 1 Innovation, employment and the skill structure



With respect to product innovation, the direct impact in a one-product firm is positive since a new demand curve will emerge (when a new product is introduced) or will shift to the right (when an existing product is improved). There is an indirect impact, though, which can be positive or negative, depending on the degree to which the demand for the new product is complementary to existing goods. If new and existing goods are complements, the introduction of the new good will cause a rise in demand for the existing good. In the case of substitute goods, demand for the existing products will decrease. Hence the overall impact of product innovations according to theory remains ambiguous.

If the firm produces more than one good, the employment effect depends on economies of scope[5] as well as the complements in the firm's demand. When economies of scope are large, the direct employment effect will be smaller, since inputs can be saved through combined production. The indirect effect depends on the demand relationship between the new or improved product and the existing products as argued above. Hence, the indirect employment effect of product innovation can be either positive or negative while the total effect depends on the parameter constellation of supply and demand functions. [6]

The discussion up to now has been concerned with the impact of innovation in a world with homogenous labour. This, however, is not realistic given that different types of skilled labour are surely not perfectly substitutable in real life innovation and transformation processes. If the number of input factors is enhanced and the labour market is modelled more realistically assuming heterogeneous labour, an economically richer structure of relationships between the input factors and innovation emerges.[7] The function of labour markets and wage setting in the different skill groups becomes important. In addition to the standard analysis, the impact of innovation will depend on the extent to which skilled and unskilled workers are

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[5] The concept has been developed by Baumol, Willig and Panzar (1982).

[6] Recent empirical studies for western industrial countries using firm data seem to confirm the ambiguity. While Entorf and Pohlmeier (1990) and König, Buscher and Licht (1995) find a positive impact of product innovation on employment in Germany, Zimmermann (1991) finds a negative impact. In the Netherlands, firms whose R&D activities are directed toward the field of information technology have a significantly higher rate of employment growth on average (Brouwer, Kleinknecht and Reijnen 1993). Entorf and Pohlmeier (1990), König, Buscher and Licht (1995) and Leo and Steiner (1994) find no negative employment impacts of process innovations in Germany and Austria. Greenan and Guellec (1995) find that over a five year period innovating firms create more jobs than other firms in France. While product innovation created more jobs at the sectoral level, process innovation created more jobs at the firm level. In France, process innovations help one firm at the expense of another. New products, on the other hand, increase employment more at the sectoral than at the firm level, and do not increase one firm's employment at the expense of another.

[7] See Hamermesh (1993).

complements and on the degree to which the types of labour and capital are complements in the production function.

If in the context of a process or a product innovation highly qualified workers are relatively more productive than less qualified workers, then the employment structure will shift in favour of the highly qualified workers (which is called „skill biased“ technological progress). Even if labour demand for all types of skilled personnel decline as a result of rationalisation, it is reasonable to assume that a more highly qualified work force will be needed to adapt to the rapidly changing technology. The hypothesis of technological progress improving qualifications has been confirmed in empirical work for western industrial countries.[8]

During the transition process in East Germany, as well as in innovation processes, new skills have become more important. Adaptive market behaviour requires the introduction of new organisational roles and the creation of an appropriate corporate culture in firms and other institutions. According to the investigation by Ewers, Fritsch and Becker (1990), in former West Germany the impact of new technology on employment and the employment structure depends on the firm’s internal organisation and its organisational rules. This has been confirmed by Campbell (1993) using a sample of firms from Great Britain, where organisational change due to process innovations was more important for employment than innovation per se.

Recently, several extensions of the basic models discussed so far have been elaborated.[9] These extensions usually do not incorporate heterogeneous labour. While the predictions of these refined models are richer, they remain ambiguous about the impact of innovation on employment, as expected. If labour markets are perfect and wages flexible, then unemployment is obviously not an obstacle in the process of change and the employment reaction by and large will be dampened relative to a world with fixed wages. [10]

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[8] See for example Bartel and Lichtenberg (1987), Bartel and Sichermann (1995), FitzRoy and Funke (1994), Kugler, Müller and Sheldon (1989) and Machin (1994).

[9] Asymmetric information in the process of knowledge distribution is discussed by Katsoulacos (1991). Better informed firms might grow faster and drive firms without the new knowledge out of the market, at least during a transition period. In an empirical study using firm data from the United Kingdom, Van Reenen (1994) finds that employment is not affected immediately after the implementation of a new product. However it rises soon afterwards and gradually declines over the following years as other firms imitate and rise to the same level as the innovating firm. A two sector model with a manufacturing and a service sector has been analysed by Cohen and Saint Paul (1994), which discusses the essential role of complements in consumers demand for the net employment impact.

[10] The role of unions and wage setting in technological progress is discussed by Ramser (1992) and Ulph and Ulph (1994), oligopolistic market behaviour by Dobbs, Hill and Waterson (1987).

The empirical part of this paper will be based on firm data. There is a difference between the impact of innovation on employment or the skill structure at the firm level and the level of the industry or the economy. The impact will, in addition to the factors discussed above, depend on competitive behaviour, market structure, wage setting in the labour market, macroeconomic conditions and technology policy. The emergence of technology, the skill structure and labour market institutions are all linked.

2.2 Remarks on endogenous innovation and human capital

Technological progress does not occur instantaneously or by chance but results from goal-oriented investment in human capital and R&D.[11] Individuals and firms make decisions about innovation, R&D and investment in human capital.[12] Development and diffusion of knowledge are crucial sources of growth, whereas human capital investment is the most important input for the advance of science and knowledge. Becker (1983) differentiates between general and specific human capital. General human capital can be transferred between sectors, companies and occupations, specific human capital cannot. As the advantages of specialisation and division of labour in a market economy are enormous, investment in specialised and often specific human capital is profitable (Becker and Murphy 1992). However, the risk of devaluation and obsolescence during technological and institutional change is higher the more specific human capital is.[13]

Depending on the type and rate of technological and economic change in a region or an industry, one can arrive at an optimal composition of general and specific human capital. General human capital is essential to keeping down the costs of creating and changing specific human capital. An unbalanced relation may slow innovation. If general human capital facilitates the creation of specific human capital in times of

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According to Machin, Ryan and van Reenen (1996) the influence of unions and collective wage bargaining on the skill structure in the US and the UK has declined in comparison to Sweden and Denmark. In Sweden and Denmark, the rate of change in the skill structure, which can be attributed to technological progress, is higher compared to the US or the UK, where wages are more flexible. Promising work on the impact of technological change on individual wages and the wage structure began with Krueger (1993), see also DiNardo and Pischke (1996).

[11] See Tirole (1989) and the literature on endogenous growth theory, for example Romer (1994).

[12] Problems arising from the non-rivalry of knowledge or of external effects of human capital in a market economy will not be discussed here further, see Acemoglu (1994) and Arrow (1995).

[13] For an empirical investigation of skill obsolescence see Blechinger and Pfeiffer (1996). If higher investment in general education reduces the variance of future income, demand for more general education will increase, Levhari and Weiss (1974).

technological change and economic uncertainty, then the returns to more general human capital will eventually rise.[14] Whether the composition of general and specific human capital is optimal or not and which role the government or the market plays in reaching this optimum remain an open questions for further theoretical research. However, it is obvious that in the context of innovation and transition the restructuring of skills is expensive, especially when wages are high and most workers already have long work histories as is the case in East Germany.

3 Innovation and skill structure in manufacturing

3.1 Measurement of innovation and human capital

In empirical investigations, innovation and human capital has to be measured. A huge bulk of literature dealing with measurement problems has emerged in the last decades. At the firm level, innovation indicators are typically either a measure of an input into the innovative process or a proxy for innovative output. Input measures are faulty since they only indicate the budgeted resources allocated towards innovative activities, rather than the actual amount of economically successful innovations. The reliability of output measures is also questionable if they solely refer to inventions (patents), irrespective of economic success. [15] Recent studies rely on self-reported statements on process or product innovations as was suggested by the Oslo Manual (OECD 1992).

This concept suggests that innovations realised in one firm might not be considered innovations by the industry as a whole. They may be imitations. Product innovations of one firm may be labelled process innovations in other firms. In effect, this appears to be the rule, since interfirm trade is quite common. On the other hand, the concept of the Oslo Manual is compatible with the theoretical concepts discussed in the previous section. The results of the econometric work therefore can be interpreted in termes of microeconomic theory.

Measuring skills or human capital is just as difficult as measuring innovation. Excellent research began with the work of J. Mincer, where human capital is identified as earnings net of educational costs over the life cycle and explained in terms of number of years in education and labour market experience. Alternatively, and more appropriately for the current work, human capital can be related to formal

[14] See Mincer (1989); if, on the other hand, economic and technological developments were perfectly predictable, it would be an advantage for individuals to specialise very early in the educational process.

[15] The different indicators have specific merits and disadvantages, see Harhoff and Licht (1994) and Licht and Rost (1996).

qualifications which are measured with indicator variables instead of number of years in school. Empirical studies reveal the relevance of additional workplace characteristics as well as work related on-the-job-training for individual wages.[16] These studies, however, normally do not measure skills and do not differentiate between general and specific human capital.

Empirical research on the basis of sector level data usually measure different types of labour as blue- and white collar employees.[17] Equipment and white collar labour seem to be complements, whereas equipment and blue collar labour appear to be substitutes. In Germany, blue and white collar workers in the official statistics are defined using the social security status and are, therefore, not a precise measure of different types of human capital.

While information on education is available at the individual level, information on innovation is available on the firm level. Usually individual level data contain only scarce information on innovation at the workplace and firm level data contain only scarce information on human capital and the skill structure of the work force. With a new firm dataset for Germany, detailed measurement of innovation has been made available. The skill structure of the workforce has been measured in accordance with formal degrees and diplomas in the German educational system. There are, however, some limitations in the measurement of the skill structure. For example, nothing is known about the age structure and the occupational status of employees.

3.2 Data

The Mannheim Innovation Panel (MIP) is an annual survey of German firms, most of them representing the manufacturing sector.[18] Since 1993, approximately 3000 firms have been successfully interviewed in Germany every year. The goal of the survey is to collect reliable information on the structure and determinants of the firm's innovative behaviour. One portion of the questions remains constant each year and the other portion, dealing with further topics, changes on a yearly basis. In the MIP, innovation is defined according to the Oslo Manual (OECD 1992). The information on innovation relates to the three years prior to the interview. It is divided into process and product innovation.

[16] For a summary see Blundell et. al. (1996).
[17] See for example Kugler, Müller and Sheldon (1989).
[18] See Harhoff and Licht (1994).

For the two parts of the empirical analysis, different surveys of the MIP are employed. [19] The first part deals with the impacts of product and process innovation on employment. The firms' labour demand growth is estimated using firms from a balanced two-year panel of the MIP 1993 and 1994. The second part investigates the complementary patterns of the firms' demand for five types of labour using the MIP 1995.[20] The data allows a distinction between four groups of labour in the production and the R&D departments of firms. Furthermore, it is possible to identify the number of employees in the administration department, however without a further division into different types of skilled labour. Labour costs of the different skill groups are not contained in the MIP data and had to be imputed by sector, region and firm size.[21]

3.3 Innovation in East and West German manufacturing firms

Table 1 shows the percentage of innovative firms in the manufacturing sector both for East and West Germany between 1990 and 1994. More than half of all firms in West Germany are innovative. Nearly half of the firms in East Germany are so as well. Over the total period, innovative activity has been lower in the East, but the difference has declined. In West Germany, innovation activity has slightly decreased, partially as a consequence of the large economic recession between 1992 and 1993. In East Germany, more firms were innovative in 1995 than in 1993. Four types of firms can be identified according to their innovative activity: product innovators, process innovators, product and process innovators and non innovators. In both parts of Germany, the majority of innovative firms realised product and process innovations.

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[19] It is restricted to firms from the manufacturing sector only. This reduces the initial number of firms by 20%. While the number of successful interviews remains nearly constant each year, the number of interviews carried out at the same firm is lower. About 30% of the firms from the first survey were successfully interviewed in the following two years.

[20] Choosing different samples is necessary because only the 1995 MIP contains information on the skill structure of the workforce.

[21] The computed labour costs are matched to the individual firm according to region, firm size, sector of activity and the five different skill groups. They are calculated using information from official statistics on wages for different sectors and skill groups (Fachserie 16, 1994). The cross wages of technical and administrative male workers in five different skill groups in East and West Germany are multiplied by a factor incorporating social security payments (unemployment, illness and pension insurance), half of the amount that the employer contributes, and other portions of labour costs like the thirteenth-month wage. The other portions of wages also differ between the sectors and are a result of wage negotiation (Kittner 1995). Since wages positively depend on firm size, estimated wage differentials for four firm size categories for East and West Germany from Geib et. al. (1992) are employed for labour cost computation. The sum of the total labour costs per employee calculated with this procedure is 3% lower than the overall labour costs reported by the firms.

Table 1: Innovative firms in East and West Germany according to type of innovation from 1990 to 1994 (in % of all firms in manufacturing)

period	1990-1992		1992-1994	
innovation type	East	West	East	West
only product innovation	8.2	21.0	5.6	9.9
only process innovation	8.6	9.4	2.0	4.4
both types	27.8	29.8	42.2	39.1
innovation (all)	44.6	60.2	49.8	53.4
no innovation	55.4	39.8	50.2	46.6

Source: MIP 1993, 1994, 1995, ZEW; number of East and West German firms in the sample: 792, 1582; 822, 1780; 724, 1718 (information on innovation is seldom missing; for 1995 for instance values are missing for 20 manufacturing firms).

Whereas the share of firms innovating only in new processes is nearly equal, the percentage of product innovators is twice as high in West Germany than in East Germany.[22] Innovation activity in East Germany is lower than in West Germany, although R&D expenditures are similar.[23] In East Germany, fewer firms are engaged in product innovation, but relatively many innovators have significantly changed existing products or introduced new products.

3.4 Skill structure in the R&D and production departments of firms

In the 1995 MIP survey, firms were questioned about the skill structure of their work force in the production, R&D and administration departments respectively. In the first two departments, four groups of workers are distinguished:

A: engineers, scientists;

B: technicians, foremen;

C: skilled workers;

D: other personnel.

[22] The intensity of innovation differs. 61.4% of the innovative West German and 62.1% of the East German firms could lower their average costs resulting from process innovations between 1992 and 1994. 77.6% of the innovative West German firms significantly changed or introduced new products in 1994 compared to 80.9% in the East.

[23] See König and Spielkamp (1995).

Table 2 contains the distribution of skills in innovative and non-innovative firms in 1994.[24] The skill structure of R&D departments in firms differs from that of production departments. The share of engineers and scientists is more than four times larger in the R&D departments in West Germany. In East Germany, the share is even higher than in West Germany. West German innovative firms have a larger share of engineers and foremen in the production departments than non-innovative firms. So the hypothesis of skill biased technological change is supported on the descriptive basis. In East Germany, there is no such difference, pointing to the special circumstances of the transition process. The starting point of the transformation has been accompanied by a poor attitude towards innovation and a poor market orientation.

Table 2: Skill structure of work force in the production and R&D departments of innovative and non-innovative East and West German firms in 1994 (in % of all firms in manufacturing)

type of firm	innovative [a]		non-innovative	
region	East	West	East	West
	production department			
engineers/scientists	11.6	8.0	11.6	6.9
technicians/ masters	7.4	9.3	9.1	8.2
skilled workers	58.0	41.4	58.5	43.3
others	23.0	41.3	20.8	41.6
	R&D department [b]			
engineers/ scientists	58.1	35.6	[c]	
technicians/ foremen	7.7	19.2		
skilled workers	30.6	25.7		
others	3.7	19.5		

Source: MIP 1995, ZEW; 934 observations; [a] a firm is said to be innovative, if it has introduced product or process innovations in the past three years; [b] contains 157 firms in the West and 7 firms in the East German sample. [c] Non-innovative firms do not have R&D-departments.

[24] Full information on the skill structure is available for about 40% (937 of the 2442) of the manufacturing firms in the 1995 MIP. This reduced number of observation might cause a problem with respect to the representiveness of the findings. To check the findings from the MIP, a detailed analysis of the qualification structure in East and West German industry as well as the qualification structure in the R&D and production departments was undertaken based on the German labour force survey from 1993. The results are documented in Appendix A and indicate that, by and large, the MIP data are reliable. Labour costs in the different skill groups are introduced in Chapter 4.

Between 1991 and 1993, there have been radical changes in employment and qualification structures in East Germany.[25] In 1993, employment levels in manufacturing had sunk to 54% of the employment levels in 1991. While the share of workers employed in manufacturing in the East has declined from 29.2% to 20% (as a percentage of overall employment), the share of workers with a university degree has risen from 8.8% to 12%. The share of workers with a vocational degree has fallen. In West Germany, employment in manufacturing has declined from 32% to 30% and the percentage of workers with a university degree has risen from 7.5% to 8.5%. In 1993, employment stood at 93% of 1991 employment levels. This indicates that the speed of job destruction and skill upgrading is significantly higher in East than in West German manufacturing.

Labour in the administration departments is not divided any further in the MIP 1995. In West German manufacturing firms about 20% of total labour is employed in this department. In innovative firms the share is 20.7%, in non-innovative firms 18.4%. In East Germany the share is around 18% and does not differ between innovative and non-innovative firms. Since firm sizes are higher in West Germany than in the East and innovative firms are on average larger than non-innovative, the difference in these numbers reflect different firm sizes. The group of adminstrative labour is presumably heterogenous as well. It contains leading managers and executive directors as well as secretarial personnel. This heterogeneity however, can not be investigated with the MIP 1995.

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[25] For more details see Appendix A.

4 Econometric analysis

4.1 The impact of innovation on employment

Based on the 1993 and 1994 MIP surveys, a labour demand equation is modelled, which explains labour demand growth through sales growth, the growth of labour costs between 1992 and 1993 and innovation.[26] Product or process innovations between 1990 and 1992 demonstrate the change in technology and products. In addition, the age of the firm is used as a proxy for capital price. Older firms might face better conditions on the capital market than younger ones. Firm size is introduced into the equation to capture differences which might occur in employment growth of small and large firms.[27] The empirical model has the following form:

$$\begin{aligned}\hat{L}_{93,92} = \beta_0 + \beta_1 \hat{Y}_{93,92} + \beta_2 \hat{C}_{93,92} + \beta_3 PD_{92} + \beta_4 PD_{91} + \beta_5 PD_{90} + \\ \beta_6 PZ_{92} + \beta_7 PZ_{91} + \beta_8 PZ_{90} + \beta_9 SZ_{92} + \beta_{10} AGE_{92} + \varepsilon\end{aligned} \qquad (1).$$

$\hat{L}_{93,92}$ represents the growth rate of labour demand (in full time equivalents), $\hat{Y}_{93,92}$ the growth rate of turnover (price * output), and $\hat{C}_{93,92}$ the growth rate of labour costs per employee (in full time equivalents), *PZ* symbolises process innovation for three years, *PD* product innovation, *SZ* firm size and *AGE* firm age. $\beta_{0,...10}$ are coefficients to be estimated; ε is the error term which is assumed to be independent and identically distributed. The equation is estimated with ordinary least squares.[28]

East Germany has experienced sales and labour cost growth of around 11% (see Table 3). In West Germany, sales have declined while labour costs have remained nearly constant. Firms in East Germany are younger and smaller than in the West. The number of firms engaged in process or product innovation has risen steadily from 1990 to 1992, especially in East Germany. The results of the estimated growth

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[26]Compared to cross-section data, the approach has the advantage that individual firm heterogeneity is eliminated. For a partial adjustment model of labour demand based on the MIP data from 1993 to 1995 see König (1996).

[27] Which is the case if Gibralt's law on the independence of firm size and growth is violated.

[28] Between 1993 and 1994 firms may have failed or refused to participate. They are, therefore, not included in the two year panel. If the failure of the firm is correlated with its size, ordinary least squares estimates may be biased. This was tested using the standard two step Heckman procedure. The Heckman correction term was, however, not significant at the 10% significance level in both samples. Therefore, the estimates can be considered to be unbiased with respect to self-selection due to failure or other non-response reasons.

equation for East and West Germany are presented in Table 3.[29] The values of the F-statistic indicate both in the eastern and western sample that the null hypothesis of no influence from all regressors has to be refused at the 1% significance level.

Sales growth shows the highest effect on the firm's labour demand. The coefficient is nearly twice as low in the East as in the West. A 10% increase in sales raises the employment level by 3.9% in East Germany and by 6.3% in West Germany. One reason for the lower elasticity of sales in the East is the lower level of capacity utilisation for East German firms. Higher sales first lead to a higher capacity utilisation and then to higher employment. Despite higher unemployment, labour costs have increased 10.6% more rapidly in East Germany than in West Germany, where the growth rate of labour costs has been about 1%. This development is the result of wage negotiations between unions and employer associations. Unions aim for a swift equalisation of West and East German wages („equal pay for equal work"). The effect of labour cost increases on employment is negative and is higher in the sample of East German firms. A 10% increase in East German labour costs induces a 2.6% lower employment level. In West Germany, employment falls by 2.2%.

The impact of innovation on employment is, in the two years under consideration, relatively small compared to the effects of labour costs and sales growth. In the case of East Germany, they are actually zero. West German firms, which were engaged both in product and process innovations between 1990 and 1992 experienced 4% higher employment growth than non-innovative firms. Product innovations only realised in 1992 had a negative impact on employment. Firms realising product innovations in 1991 had an 8% higher growth of labour demand than their competitors who had not undertaken innovation activity in 1991. The positive impact of early product innovations dating back to 1990 has already diminished, indicating competition or market satiation. Whereas process innovation did not influence labour demand in East Germany, a slightly negative impact was observed for West Germany. Especially process innovations introduced in 1991 reduced firms' labour demand by 6%.

The age of a firm is not significant. In West Germany, the level of employment has no impact on labour demand either. In East Germany, employment growth decreases with firm size. Results from empirical firm level studies cannot be generalised to aggregate levels, since indirect impacts, which often occur in the medium or long run in other firms and industries, cannot be identified. However, it is reasonable to argue

[29] The equations have been tested for heteroscedasticity of the disturbance variance (with the Breusch/Pagan/Godfrey test). The test revealed heteroscedasticity in the West German labour demand growth equation, but not in the East German one. Accordingly, Table 3 contains heteroscedastic-consistent standard errors for the West German sample.

that the overall employment impacts of innovations are underestimated in our model. First, indirect impacts of innovation are more likely to be positive than negative, especially in East Germany. In the course of transition, early economic success is likely to breed ensuing successes. Second, our sample only contains data of firms which already existed in 1992. The birth of new firms can enhance employment in the medium term.

Table 3: Employment growth equation between 1992 and 1993 in East and West German firms from the manufacturing sector

region	East			West		
variable	mean[a]	coefficient	t-value	mean[a]	coefficient	t-value
sales growth	0.11 (0.50)	0.39	9.34***	-0.04 (0.37)	0.63	5.29***
growth of labour costs	0.11 (0.47)	-0.26	-6.10***	0.01 (0.39)	-0.22	-4.89***
product innovation						
1990	0.21	0.01	0.11	0.56	-0.05	-1.12
1991	0.47	-0.05	-0.99	0.63	0.08	1.57
1992	0.59	0.05	0.82	0.66	-0.07	-2.11**
process innovation						
1990	0.13	0.04	0.54	0.38	-0.01	-0.15
1991	0.38	-0.02	-0.27	0.43	-0.06	-1.61
1992	0.48	0.01	0.21	0.48	0.02	0.46
firm size (in logs)	4.03 (1.37)	-0.08	-5.20***	4.88 (1.89)	-0.01	-0.62
firm age (in logs)	-0.88 (4.09)	0.01	1.23	3.10 (1.73)	-0.01	-0.63
constant		0.26	3.85***		0.07	1.84*
		F-test			F-test	
product innovation		0.36			1.56	
process innovation		0.13			1.93*	
both types of innovation		0.30			2.09**	
all regressors		18.87***			5.76***	
observations		267			609	

Source: MIP 1993, 1994, ZEW; ordinary least squares regression with heteroscedastic-consistent standard errors (Huber formula) in West Germany; *** significant at the 1% level; ** significant at the 5% level; * significant at the 10% level; [a] standard deviation in parentheses.

Be this as it may, the results of Table 3 may be criticised for another reason. It is assumed that labour is a homogenous input. If labour were heterogeneous instead, a more complicated substitution pattern might exist between the types of labour and capital. The coefficient of labour costs is likely to be underestimated if wage growth is higher in low and medium skilled labour groups relative to high skilled ones. A more differentiated analysis is possible on the basis of the MIP 1995 survey.

4.2 Heterogeneous labour and capital as complements or substitutes in the production function

4.2.1 Rank correlation analysis

Before examining the firm's demand for various skilled workers within the framework of a translog production function, the rank correlation of the shares of employees in each qualification group in the production and R&D departments of the manufacturing firms in 1994 are discussed (using 1995 MIP data, see Table 4).

Table 4: Rank correlation between four skill groups in the production and R&D departments of manufacturing firms in 1994

skill type	engineers/scientists		technicians/ foremen		skilled workers	
region	East	West	East	West	East	West
technicians, foremen	0.18***	0.42***				
skilled workers	-0.12**	0.16***	-0.14**	0.23***		
others	-0.30***	-0.44***	-0.15***	-0.47***	-0.81***	-0.90***

Source: MIP 1995, ZEW; rank correlation coefficients of Spearman and test of independence between each two qualification groups; *** significant at the 1% level; ** at the 5% level.

The rank correlation analysis suggests a hierarchic pattern in the labour market. The highest correlation values are given for every two closely related groups. For example, the rank correlation between engineers/scientists and the other groups is higher for technicians/foremen (0.42), than for skilled workers (0.16) and for the other workers (-0.44). In East and West Germany, the rank coefficient is -0.8 and -0.9, respectively, highest for the group of skilled workers and other personnel. In contrast, the employment of engineers/scientists and technicians/foremen is positively (rank-) correlated in eastern and western production and R&D departments of manufacturing firms. Whereas skilled workers in the western part of Germany are positively correlated to engineers/scientists and technicians/foremen, in the eastern part of Germany, a high share of engineers/scientists is correlated with a low share of skilled workers.

The values reported in Table 4 are instructive. The substitution as well as complementary patterns in firms' labour demand, however, are determined by technology, input factor costs, administrative labour and different capital equipment. A deeper understanding is possible within a production theory approach, which is presented next.

4.2.2 Translog production function analysis

It is assumed that firms in the manufacturing sector have a transcendental logarithmic (translog-) production function introduced by Christensen, Jorgenson and Lau (1970):

$$\ln Y = \alpha_0 + \sum_{i \in \Omega} \alpha_i \ln X_i + 1/2 \sum_{i,j \in \Omega, i \neq j} \beta_{ij} \ln X_i \ln X_j \qquad (2)$$
$$\Omega = \{H, M, L, A, C, P\}$$

Y stands for annual output, *X* for inputs. Ω contains the indices of the six different input factors. *H*, *M*, *L* stand for high skilled workers (engineers, scientists, technicians, foremen), medium skilled workers (workers with a vocational degree, termed skilled labour in Table 4) and low skilled (other personnel) in the production and R&D departments. Engineers/scientists and technicians/foremen had to be grouped together because otherwise the number of observations would have been too small in each group. *A* represents total labour in the administration department, which cannot be differentiated further, *C* is capital equipment (total tangible property of a firm), *P* material purchases. α_0 represents the state of technological development; α_0, α_i, β_{ij}, $i,j \in \Omega$, are parameters to be estimated. Since the firm's physical output is not available in the data, turnover will be used instead (price * output).

The production function is assumed to be well behaved with constant returns to scale. Firms are assumed to be pricetakers in input and output markets. Profit maximisation leads to first order conditions, which can be formulated as a set of factor cost shares, the sum of which has to add up to one. Stochastic versions of the production and cost shares function constitute a system of seemingly unrelated equations. To ensure invariance with respect to the choice of dropping one cost share function, the system has been estimated with the maximum likelihood method.[30] This system of equations

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[30] As proposed by Berndt and Christensen (1973). It is furthermore assumed that the disturbances in the cost share equations, which may be attributed to a variety of forces like deviations from competitive behaviour or technological inefficiency, are distributed normally. For a detailed

has been estimated separately for innovative and non-innovative manufacturing firms in East and West Germany since the research interest is directed toward the complementary structure of different input factors in the process of technological change.

4.2.3 Labour cost in East and West German manufacturing firms

Before turning to estimated elasticity, information on labour costs of the different input factors is given in Table 5. Labour costs in East German manufacturing firms total about 60 to 70% of West German ones. Labour costs increase with the degree of qualification. Labour cost differences for all closely related qualification groups are lower the less educated workers are. The gap between average labour costs in the group of scientists and the group of other personnel is higher in West than in East German firms.

Table 5: Average annual labour costs of five groups of skilled workers; (in thousands of DM)

region	East Germany		West Germany	
mean; min. / max.	mean	min. / max.	mean	min. / max.
engineers/scientists (*H*)	62.7	50.2 / 75.3	104.2	80.7 / 136.3
technicians/foremen (*H*)	52.7	39.9 / 65.8	81.4	60.8 / 99.6
skilled workers (*M*)	41.6	30.6 / 59.5	64.5	48.4 / 83.7
others (*L*)	36.3	25.9 / 51.4	54.7	42.1 / 69.9
administration (*A*)	58.9	46.2 / 67.2	89.8	71.0 / 110.0

Source: analysis based on data from official statistics on wages for different sectors and skill groups and estimated firm size wage differentials (see Section 3.2) and the MIP 1995.

The mean cost for labour in the administrative department of the firms lies between the costs for engineers and technicians. So on average, administrative labour belongs to the group of high skilled labour.

The total share of labour costs on turnover amounts to roughly 36%, being slightly higher in non-innovative (37%) than in innovative firms (35%). Cost shares of the different types of labour costs (with respect to total labour cost) varies in the entire sample of firms between 5.7% for scientists and 12.4% for medium skilled personnel.

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discussion of different specifications of the production function, its properties as well as econometric issues, and a complete description of the empirical results, see Falk and Pfeiffer (1997). The estimated coefficients are, with only a few exceptions, all significant at the 5% level. The results do not change in any significant way, when the production function contains a set of dummy variables of firm size and industries.

In non-innovative firms in East Germany, the latter share is highest, with a value of more than 17%.

4.2.4 Own and cross factor price substitution elasticity

The discussion of the econometric results concentrates on the signs and relative magnitudes of selected substitution elasticity between the different types of inputs. The Slutsky-elasticity measures the total responsiveness of factor *i* to changes in the price of factor *j* (termed w_j). They need not be symmetric and are defined as:

$$\sigma_{ij} = d \ln X_i \,/\, d \ln w_j \;; \quad \forall\; i, j = H, M, L, A, C, P. \qquad (3)$$

Firms with different cost shares have different elasticities. The elasticities presented in Table 6 are calculated at the respective sample mean. All own factor price elasticities are negative, in accordance with economic theory.[31] The absolute values are larger in East German than in West German firms. So, in East Germany the industrial firms' labour demand reacts more strongly to wage changes than in West German industrial firms, which confirms the previous results. Elasticities rise with the skill level and are, with the exception of non-innovative East German firms, highest in the group of high skilled labour. If elasticity indicates the degree of competition in markets, this result suggests higher competition in the group of high skilled labour. In East Germany, labour demand elasticity is highest in innovative firms for high skilled labour and in non-innovative firms for low skilled labour. Capital and material purchases elasticities are lower than the labour input elasticity.

Turning attention to cross factor price elasticities, one can conclude from Table 6 that most input factors are substitutes or neutral. By and large, the numerical values of the cross price elasticities are smaller than that of the own factor price elasticity. Therefore, the indirect impacts of changes in the labour cost of one skill group are smaller than the direct ones, which seems reasonable. The estimated cross price elasticities are positive in general.

Table 6: Elasticity of substitution in East and West German innovative and non-innovative manufacturing firms in 1994 (selected results)

[31] The values of the own factor price elasticities are relatively large compared to the estimates of the dynamic labour demand function in Section 3.1. The reason behind the high values are at least in part the result of imputed cost shares, instead of having individual firm cost shares. The higher elasticity of high skilled labour is, in addition, a result of aggregation of the two highest skill groups. Labour costs between these differ significantly and the two groups can be substituted. Therefore the elasticity is likely to be overestimated.

type of firm	innovative		non-innovative	
region	East	West	East	West
	own factor price elasticity			
σ_{CC}	-1.37	-1.42	-1.64	-1.56
σ_{HH}	-11.66	-4.55	-6.04	-3.60
σ_{MM}	-2.98	-3.01	-4.53	-2.35
σ_{LL}	-4.27	-2.33	-11.34	-2.15
σ_{AA}	-2.95	-2.11	-2.20	-1.85
σ_{PP}	-2.53	-1.71	-2.52	-1.75
	cross factor price elasticity: capital, types of skilled labour			
σ_{HC}	0.44	0.18	0.67	0.48
σ_{MC}	0.02	0.26	0.32	0.10
σ_{LC}	0.12	0.27	-1.00	0.11
σ_{AC}	-0.40	0.04	-0.33	-0.20
σ_{PC}	0.37	0.27	0.41	0.34
σ_{CH}	0.24	0.08	0.39	0.24
σ_{CM}	0.02	0.22	0.50	0.11
σ_{CL}	0.06	0.22	-0.46	0.13
σ_{CA}	-0.29	0.04	-0.33	-0.24
σ_{CP}	1.33	0.86	1.54	1.33
	cross factor price elasticity: administrative, high, medium, low skilled labour			
σ_{MH}	1.79	0.61	1.35	0.27
σ_{LH}	0.19	0.35	2.30	0.18
σ_{HM}	4.39	1.14	3.67	0.61
σ_{HL}	0.18	0.62	1.86	0.42
σ_{LM}	1.61	0.25	0.16	0.43
σ_{ML}	0.62	0.24	0.05	0.45
σ_{HA}	0.28	0.79	0.56	0.71
σ_{MA}	0.12	0.24	0.31	0.28
σ_{LA}	-0.42	0.04	2.03	0.04

Source: calculated from the estimated parameters of the translog function, see Appendix B; for definitions of symbols see equation 2 and 3; based on the MIP 1995 and imputed cost shares.

There are two exceptions. First, capital and low skilled labour are complements in East German non-innovative firms. Most of the non-innovative firms will still belong to the group of firms which are governed by the state owned „Treuhand Anstalt“. Second, capital and administrative labour are complements in East Germany and in non-innovative firms in West Germany. The higher the amount of capital, the more administrative workers are employed in the firms.[32] There are at least two possible explanations for this result. One, the management of the transition needs additional administrative staff. Two, extended government funding of investment requires administrative staff. As a result, firms which more effectively raise government funds have higher amounts of capital and also administrative staffs.

The analysis allows no direct discrimination between these alternative explanations. However, the most likely explanation is hypotheses two, since in non-innovative, West German firms administrative labour and capital are also complementary, although the estimated value is smaller than in East Germany. Capital and administrative labour is complementary with the exception of innovative West German firms. Leading managers in existing firms can profit from a good understanding of state subsidies and the different funds for getting money for investment as well as R & D. Given the amount of official funds for transforming East Germany to a market economy, it might be even more profitable to compete for these funds instead of competing in the market.

The traditional hypothesis of capital complementing skill can be rejected according to the result. Capital equipment and skilled labour are substitutes in German industrial firms with the exception of capital and administrative labour. Instead, a modified version of the capital skill complementarity hypothesis seems to hold true. In West German innovative firms, the absolute value of the elasticity is rather small (0.18 compared to 0.48 in non-innovative firms). In East German innovative firms, the value is 0.44, in non-innovative firms 0.67. A fall in the price of capital will lead to a fall in the employment of high skilled labour, which is smallest in West German innovative firms. In the other three samples, firms' demand for medium and low skilled labour reacts less than in the sample of innovative West German firms.

Firms at the forefront of technological progress, which are most likely to be West German innovative firms, will more easily substitute medium and low skilled labour for capital. High skilled labour and capital are substitutable only to a lesser degree. In non-innovative firms on the other hand, capital and medium and low skilled labour are nearly neutral, while capital and high skilled labour is more substitutable. Presumably, capital equipment is older in non-innovative firms and high skilled labour is not necessary to the same extent as medium and low skilled labour.

The last types of elasticities explain the substitution pattern between the different groups of skilled labour. The results indicate that the different types of labour can be substituted more easily than labour and capital. Furthermore, the degree of

[32] One must keep in mind that administrative labour cannot be further differentiated due to data restrictions.

substitution in labour demand for scientist/technicians (high skilled labour) and medium skilled workers is higher than between labour demand for medium skilled workers and other personnel (low skilled labour).[33] In innovative firms, cross factor price substitution elasticity between high and medium skilled labour is larger than in non-innovative firms and between low and medium skilled labour. High and medium skilled labour can be substituted more easily in innovative than in non-innovative firms. Since the difference between innovative and non-innovative firms can be interpreted as a measure of technological progress, the results reject the skill bias hypothesis.

With the exception of non-innovative East German firms, the elasticities between high and low skilled labour is lower than the ones between medium and high skilled labour. If the price of medium skilled labour rises (other factor remaining equal), innovative firms will react with an increase in the demand for high skilled labour, which is nearly four times larger in the East than in the West. An increase in the demand for low skilled labour, which will be smaller in absolute values (in accordance with the rank correlation analysis above), arises at the same time. If the price of low skilled labour rises, firms will react with an increase in the demand for high and medium skilled labour, the latter being lower than the former in West German innovative firms.

Administrative labour is by and large more substitutive to high than to medium and low skilled labour in the West. Furthermore administrative labour is more subsitutive to in the West than in the East, with the exception of non-innovative East German firms, wehre low skilled labour in production and R&D departments and administrative labour are highly substitutive. That may indicate that in East Germany, especially in non-innovative firms, administrative skills are rather scare, while low skilled labour is abundand leading to substitution processes.

It makes a difference whether one considers the effects of a price change in factor *i* on the demand for factor *j* or vice versa. In West German innovative firms there is a clear pattern. Price changes in the lower skill group have a larger impact on the quantity reaction in the higher skill group than the reverse. The speed of skill upgrading in the process of technological change will be higher in the industrial sector, should labour costs rise overproportionally in lower skill groups. A similar pattern has been found in the other samples for skill upgrades from medium to high skilled labour. By and large, the substitutability between low and medium skilled labour is smaller than between medium and high skilled labour. One can therefore conclude that medium skilled labour, composing the majority of employees in German industry, is substituted by high skilled labour. Its speed of adjustment

[33] This differs from the result of the rank correlation analysis.

depends on the current state of technology and the pressure of wages set by the labour market. Compared with this, the speed of skill upgrading from low to medium skilled labour seems to be lower.

4.3 Capital, R&D, training or wage subsidies for creating employment?

Labour demands at various skill levels are linked through substitution processes, markets and institutions. In 1995, more firms expected a further rise in the demand for high and medium skilled labour and a further decline in that of low qualified labour until 1997.[34] The process of skill upgrading will continue, especially in R&D departments. The share of East German firms, for whom the lack of skilled labour is a significant barrier to innovation, has declined from 39.3% in 1993 to 22.8% in 1995.[35] Skilled labour was therefore less common in 1993 than 1995 (from the viewpoint of the firms in the MIP survey). Job destruction on one hand and training activities by firms and retraining of unemployed by the government on the other hand have improved the situation for firms. The problem of high unemployment, however, has not been solved yet.[36] Preliminary policy conclusions can be derived from the above results.

Increases in labour costs (all else remaining equal) are one source of employment declines, since in private enterprises only workers who's marginal productivity equals their marginal cost are employed.[37] Labour is, however, a heterogeneous input with complex patterns of substitution. Changes in labour costs will have different impacts according to the types of labour affected.

Labour costs can be divided into the following three parts: those which are determined by the government (payments to the social transfer system), those which are determined mainly by firms (pension funds and fringe benefits) and those which are determined by negotiation between unions and employer associations (wages,

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[34] See Appendix C and Licht et al. (1996).

[35] In the MIP survey, firms are asked about the relevance of 14 different barriers to innovation, like lack of skilled labour, restrictive regulations, and the lack of appropriate sources of finance. The lack of finance had been a problem for nearly 50% of the firms in East Germany, and 30% of the firms in West Germany in 1995, see Appendix D. The lack of finance seems to be more important than the lack of skilled workers. This is surprising, given the amount of government investment support in East Germany, see Sinn (1995). Firms answers may be biased in favour of arguing that the lack of appropriate financing sources is a problem.

[36] Unemployment is higher the lower formal qualifications are. In West Germany in 1993 14% of individuals with a vocational degree were unemployed, in East Germany 42%. In West Germany about 4% of individuals with a university degree were unemployed, in East Germany 8.5%.

[37] Already Sinn and Sinn (1991) blamed high wages for high rates of job destruction and unemployment in East Germany.

working time, holidays). The percentage of labour costs in the three parts varies between skill levels. In high skilled labour markets, unions and employer associations usually have less direct impact on wages and the share of social security payments (leaving taxes aside) is lower. A reduction in the part of labour costs which are determined by law would, for instance, lead directly to a greater rise in medium and low skilled employment than in high skilled employment (given that the other parts of labour costs stay constant). The demand for high skilled labour would furthermore fall through an indirect substitution effect.

Labour cost reductions through a decline in wage or non-wage costs are difficult to realise for political reasons. Wage rates as well as working time for medium or low skilled labour are determined by unions and employer associations. In the past, wage rate reduction were not the rule, neither in East nor in West Germany, despite high and rising unemployment. Wages and labour costs seem to be rather inflexible downward in Germany, an idea which has been prominent since the work of J.M. Keynes. Even wage distributions may be inflexible.

Wages in the private sector cannot be too small relative to the public sector. Wages in the public sector are compared to the wages in West Germany.[38] The aim of the unions is to balance the wages as fast as possible, in the public sector as well as in other sectors. Together with the considerable cost of adjusting workers' skills, there is a lot of pressure on the process of job destruction and skill upgrading, especially in low and medium skill groups. Furthermore, the chance of a reduction in the part of labour costs determined by the government is also quite small. From the viewpoint of the present results, a strategy for job creation in East Germany (at least in the current stage of transformation) may lie in subsidising labour (see also Akerlof et. al 1991 and especially Sinn, 1995). According to the differing elasticity in labour demand for different skill groups, subsidies could differ and be lowest for high skilled labour. Subsidising labour leads to a direct reduction in labour costs, which most likely has the largest employment impact.

The German government strategy to create employment in East Germany currently seems to rely on promotion of investment in capital equipment, R&D and retraining of the unemployed. The former two measures are intended to shift labour demand outward. Raising workers' productivity via government financed training will not solve the unemployment problem, if labour demand cannot be shifted outwards. Worse, should labour demand stay constant and should training raise marginal

[38] 'On one hand, we have a fairness gap between East and West. Often civil servants from the East and West, who have different incomes, sit in the same office. The second fairness gap exists in the fact that employees in the public sector draw higher incomes than workers in the private sector.' Own translation of a quote from Reinhard Höppner, Prime Minister of Sachsen-Anhalt, in Handelsblatt 26./27.7.1996 Nr 143.

productivity, employment will actually decline. The effectiveness of training and retraining measures is, therefore, likely to be low if firms' labour demand is not enhanced.[39] Furthermore, East German workers are often (re-)trained in rather specific vocational skills and occupations which are well established in West Germany. There is a risk in this type of retraining, since firms' future demand for specific vocational skills may change in the transformation process.

In order to employ all East German workers with wages matching their formal qualifications before or after retraining, high growth rates are necessary, especially in industries with a large share of skilled labour. Since labour costs are already high at the start, the process of trial and error in creating new markets is dominated by state owned firms or by internationally competitive firms from West Germany or abroad. These are often large, risk averse firms who invest only in new processes and products where they can calculate the risk. Public choice arguments suggest that officials, who decide about financing risky projects and which firms are to be subsidised, are also risk averse. Therefore, the more effective strategy for creating employment, seems to lie in wage subsidies.

[39] For recent empirical evidence see Lechner (1996).

5 Concluding remarks

The paper focuses on the relationship between innovation activity and human capital at the firm level. Empirical labour demand functions for heterogeneous labour, including two types of capital, in innovative and non-innovative East and West German firms, have been compared using the MIP 1995. The impact of innovation on employment has been estimated with a two period panel dataset (MIP 1993, 1994) for East and West German manufacturing firms. According to the results, firm behaviour in the manufacturing sector differs between the two parts of Germany. It is shown that complex patterns of substitution between capital and different types of labour emerge, which depend on the stage of economic transformation, the type of firms, wage setting behaviour and interventions by public policy. The results suggest that in the current stage of transition subsidising labour might be more effective for creating jobs in East Germany than promoting R&D and capital equipment.

Some critical remarks on the data and estimation are, however, necessary. The econometric analysis may suffer from the following drawbacks. First, the database does not contain labour costs for the five types of labour at the firm level. Instead, they had to be imputed and matched by region, firm size and industrial sector. Second, labour in the administration department of the firms is not differentiated by skill levels. Third, the information on the skill groups is missing for nearly 60% of the firms in the sample. Fourth, the intensity and types of innovation differ, which is not controlled for in the second analysis. Fifth, for the second model it is assumed that input and output markets are governed by perfect competition, which can be questioned. Sixth, the disturbance term in the cost share equations is not normally distributed. The substitution elasticity may be distorted for each of these reasons. The difference between innovative and non-innovative firms in East and West Germany may be smaller than the estimates suggest. Finally, the paper is restricted to the manufacturing sector, which is shrinking in both East and West Germany. While in West Germany 30% of employees are in the manufacturing sector, in East Germany only one out of five workers is employed there. It is likely that job decline in the manufacturing sector will continue.

Some of the drawbacks have their origin in the data source, others in the complexity of econometrics. The focus has been on innovation and heterogeneous labour in a cross section. In future work, more complex economic and econometric models should be considered, which can, for instance, take into account imperfect input and output markets and the dynamic nature of skill biased technical change. Furthermore, in future work it is possible to analyse the service sector with firm level data, using the first wave of „Mannheim Dienstleistungspanel“ from 1995 (see infas/ ZEW/ FHG/ ISI, 1996).

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7 Appendix

Appendix A Qualification Structure in East and West German Industry

Education and training was an integrate part of the socialist ideology in former East Germany. As a result, formal schooling as well as vocational training was and still is higher in East than in West Germany (since the fall of the wall in November 1989, the differences and similarities of the education and vocational training system and the structure of human capital in the two parts of Germany has been intensively investigated, see for instance Krueger and Pischke 1992, Geib et. al. 1992).

In former East Germany there was a dual vocational training system comparable to the West. The system had its roots in both parts of Germany before the division of Germany after World War II. With unification, the formal school and apprenticeship degrees of the former East were not eliminated. They have remained valid (Bundesberufsbildungsgesetz, BBiG 1994, §108). However, as a result of unification, human capital in East Germany has deteriorated. The age - income profiles have levelled in the eastern part of Germany compared to the western part.

The qualification structure in East and West German manufacturing industries will be compared using the two surveys from the 70%-ZEW-sample of the German „Mikrozensus 1991, 1993“ (Table A). While there is structural change in both parts of Germany, the velocity of change is higher in the East. In former East Germany, 8,55 million people were employed (Statistical Yearbook for East Germany, 1990), in April 1991 the number was 7,51 million and in April 1993 6,27 million (the number of April 96 is 6,31 million). Unemployment has risen considerably. The share of workers in the manufacturing sector relative to all workers has declined in East Germany from 29.2% in 1991 to 20.2% in 1993, in West Germany from 32% to 30%.

Vocational qualification has been divided into five categories (in the official Mikrozensus data there are seven categories, see Pfeiffer and Brade 1995):

1. university degree (13 years of schooling; 5 years training at university); (A)
2. technical university degree (12-13 years of schooling; 4 years training at university) (A);
3. foreman certificate (vocational training and in addition one extra year of training) (B);
4. vocational training (2.5 to 3.5 years of vocational training) (C, D);
5. no formal degree (D).

The categories A, B from the MIP data are equivalent to Mikrozensus categories 1, 2 and 3. There is no equivalent to category D „other personnel“ from the MIP and the „Mikrozensus“ categories. However, it is reasonable to suggest that the MIP category D contains workers from the „Mikrozensus“ categories 4 „vocational training“ and 5 „no degree“. A worker in the industry, for instance, might have a vocational degree from the trade sector. In this case an industrial firm might categorise the worker under „other personnel“, while in the „Mikrozensus“ the worker categorises himself under „vocational degree“.

Table A contains the frequency distribution of workers in the five different skill levels in East and West Germany in 1991 and 1993 in manufacturing firms and in the production and R&D department of firms separately.

Table A: Qualification structure of workers 1991 and 1993 in production and R&D departments in East and West manufacturing (in %)

degree	no degree	voc. degree#	foremen	tec-univ.#	university
East	*production department (in % of total 1991:68.8, 1993:70.2)*				
1991	4.8	77.3	14.0	1.5	2.5
1993	3.2	78.1	13.0	2.4	2.8
West	*production department (in % of total 1991:65.5, 1993:66.6)*				
1991	24.2	64.4	9.2	1.5	0.9
1993	22.8	64.6	10.0	1.7	1.0
East	*R&D department* (in % of total 1991:5.9, 1993:5.3)*				
1991	0.6	27.5	30.5	10.6	31.0
1993	2.0	23.4	18.9	13.3	42.3
West	*R&D department* (in % of total 1991:6.9, 1993:7.0)*				
1991	0.4	36.3	22.1	22.1	15.7
1993	3.5	35.6	21.0	22.4	17.6
East	*total (1993 in % 1991: 54.1%; share of all workers: 1991, 29.2%; 1993, 20.2%)*				
1991	4.1	69.6	17.1	2.6	6.6
1993	3.0	68.9	16.2	4.2	7.8
West	*total (1993 in % 1991: 92.8%; share of all workers: 1991, 32.0%; 1993, 30.0%)*				
1991	19.4	63.0	10.2	4.1	3.4
1993	18.1	62.8	10.6	4.6	3.9

Source: Analysis based on the ZEW-70% sample of the German „Mikrozensus“ 1991, 1993 (with official weight factors, Pfeiffer and Brade 1995); #voc.-degree = vocational degree, tec.-univ. = technical university; *research, development, construction and design.

The share of workers without any vocational degree in manufacturing is four times higher in West Germany than in East Germany. With the exception of the share of workers with a technical university degree, the proportion of all other categories is higher among East German workers than among West German workers.

The numbers in the table show structural change, which is visible in both parts of Germany, but more so for East Germany. In West Germany, the share of workers with a university degree (technical and others) has risen from 7.5% to 8.5%, while the share of workers without a vocational degree has declined. In East Germany, the share of workers with a university degree has risen from 8.8% to 12%. The qualification structure differs between production and R&D departments, which cover together about ¾ of all workers. In West Germany, the share of workers in R&D is higher than in East Germany, where the share has fallen further slightly between 1991 and 1993. In West German production departments the percentage of workers with a university degree lies below 3%, in the R&D departments it is nearly 40%. In East German production departments the percentage of workers with a university degree lies above 5%. It has risen to 55% in the R&D departments in 1993. The qualification structure in the R&D departments in the two parts of Germany differs. In West Germany, there are more workers with a technical university and vocational degree. In East Germany, workers with a university degree dominate.

Appendix B: Estimation results of the translog production function

Table B: Translog production function parameter estimates for East and West Germany (standard errors in parentheses)

type of firm	innovative		non-innovative	
region	East	West	East	West
observations	108	351	84	204
α_0	0.281 *(0.0692)*	0.325 (*0.0382)*	0.303 *(0.0999)*	0,279 *(0.0283)*
α_H	0.060 *(0.0080)*	0.077 *(0.0033)*	0.075 *(0,0076)*	0.075 *(0.0038)*
α_M	0.034 *(0.0148)*	0.060 *(0.0067)*	-0.042 *(0.0220)*	0.078 *(0.0087)*
α_L	0.054 *(0.0124)*	0.049 *(0.0070)*	0.046 *(0.0118)*	0.054 *(0.0091)*
α_A	0.065 *(0.0393)*	0.128 *(0.0157)*	0.152 *(0.0485)*	0.120 *(0.0157)*
α_C	0.157 *(0.0275)*	0.163 *(0.0126)*	0.147 *(0.0370)*	0.104 *(0.0116)*
α_P	0.653 *(0.0211)*	0.593 *(0.0098)*	0.687 *(0.0226)*	0.624 *(0.0106)*
β_{CC}	0.032 *(0.0053)*	0.051 *(0.0032)*	0.042 *(0.0103)*	0.044 *(0.0036)*
β_{HH}	0.061 *(0.0034)*	0.047 *(0.0013)*	0.054 *(0.0028)*	0.040 *(0.0018)*
β_{MM}	0.089 *(0.0042)*	0.074 *(0.0021)*	0.125 *(0.0061)*	0.071 *(0.0028)*
β_{LL}	0.048 *(0.0033)*	0.064 *(0.0020)*	0.049 *(0.0031)*	0.071 *(0.0029)*
β_{PP}	0.185 *(0.0063)*	0.162 *(0.0036)*	0.179 *(0.0053)*	0.160 *(0.0035)*
β_{AA}	0.053 *(0.0168)*	0.060 *(0.0039)*	0.052 *(0.0138)*	0.061 *(0.0047)*
$\beta_{CH} = \beta_{HC}$	-0.004 *(0.0018)*	-0.003 *(0.0008)*	-0.005 *(0.0017)*	-0.004 *(0.0010)*
$\beta_{CM} = \beta_{MC}$	-0.004 #*(0.0030)*	-0.007 *(0.0015)*	-0.013 *(0.0047)*	-0.002 #*(0.0021)*
$\beta_{CL} = \beta_{LC}$	-0.004 #*(0.0028)*	-0.007 *(0.0016)*	0.002 #*(0.0027)*	-0.003 *(0.0024)*
$\beta_{CP} = \beta_{PC}$	-0.036 *(0.0051)*	-0.025 *(0.0023)*	-0.031 *(0.0052)*	-0.028 *(0.0027)*
$\beta_{CA} = \beta_{AC}$	0.005 #*(0.0092)*	0.000 #*(0.0027)*	0.013 #*(0.0100)*	0.011 *(0.0032)*
$\beta_{HM} = \beta_{MH}$	-0.016 *(0.0025)*	-0.009 *(0.0011)*	-0.017 *(0.0026)*	-0.007 *(0.0013)*
$\beta_{HL} = \beta_{LH}$	-0.004 *(0.0018)*	-0.006 *(0.0008)*	-0.004 *(0.0014)*	-0.005 *(0.0010)*
$\beta_{HP} = \beta_{PH}$	-0.028 *(0.0023)*	-0.023 *(0.0011)*	-0.020 *(0.0016)*	-0.020 *(0.0013)*
$\beta_{HA} = \beta_{AH}$	-0.005 #*(0.0034)*	-0.008 *(0.0011)*	-0.009 *(0.0022)*	-0.007 *(0.0014)*
$\beta_{ML} = \beta_{LM}$	-0.014 *(0.0026)*	-0.009 *(0.0014)*	-0.008 *(0.0031)*	-0.013 *(0.0020)*
$\beta_{MP} = \beta_{PM}$	-0.051 *(0.0035)*	-0.042 *(0.0020)*	-0.070 *(0.0040)*	-0.041 *(0.0024)*
$\beta_{MA} = \beta_{AM}$	-0.009 #*(0.0053)*	-0.010 *(0.0018)*	-0.018 *(0.0060)*	-0.011 *(0.0025)*
$\beta_{LP} = \beta_{PL}$	-0.024 *(0.0034)*	-0.036 *(0.0020)*	-0.025 *(0.0027)*	-0.042 *(0.0023)*
$\beta_{LA} = \beta_{AL}$	-0.001 #*(0.0047)*	-0.005 *(0.0018)*	-0.010 *(0.0038)*	-0.004 #*(0.0024)*
$\beta_{PA} = \beta_{AP}$	-0.045 *(0.0077)*	-0.045 *(0.0026)*	-0.042 *(0.0070)*	-0.047 *(0.0032)*

Source: Maximum likelihood of seemingly unrelated regression model, based on the MIP 1995 using gross annual labour costs as reported in Table 5 in the text. Coefficients not significant at the 5% level are marked with #.

Appendix C: Employment expectations

The trend toward higher qualification will continue in the near future. In Table C the results of individual firms' employment expectations for the various qualification groups in the production and R&D departments over the next two years are reported in qualitative terms („decrease", „no change", „increase"). More firms expect an increase than a decrease of highly qualified workers. Only 4% of western firms and 5% of eastern firms plan a decrease of engineers, researchers and highly qualified technicians. Conversely, 27% of West German and 20% of East German firms see additional potential for high qualified workers. On the other hand, a stagnation in the demand for other personnel can be expected, since nearly the same percentage of firms are planning an increase as are expecting a decrease (22% and 23%, respectively). 47% of East German industrial firms expect an increase in the group of medium skilled labour compared to only 32% in West Germany.

The trend toward a higher demand for engineers/scientists is especially prevalent in firms with separate R&D department. Only 4% of western and 1% of eastern firms plan an increase in the demand for other personnel. 43% of the firms in the eastern part and 30.5% in the western part of Germany expect an increase in engineers and scientists. In sum, more firms plan to increase instead of decrease employment for qualified workers, both in East and West Germany. In East Germany, however, the difference is smaller for the two highest qualification groups. Over the next two years, the long term trend towards more highly qualified workers will continue in West Germany. In East Germany, there is a need for medium skilled labour, which is a result of the inherited qualification structure of labour.

Table C: Expected labour demand in production and R&D departments of industrial firms in 1995 (in per cent of all firms; expectations for 1995 to 1997)

expectations	decrease		no change		increase	
region	East	West	East	West	East	West
production department						
engineers/ scientists	5.0	3.8	74.7	68.8	20.4	27.4
technicians/ foremen	5.6	7.0	75.4	71.8	19.0	21.2
skilled workers	8.6	13.9	44.4	53.8	47.0	32.3
others	22.7	26.7	57.2	51.6	22.7	21.7
R&D department						
engineers/ scientist	8.8	2.9	60.7	54.1	30.5	43.0
technicians/ masters	5.4	5.7	90.7	71.2	3.9	23.1
skilled workers	9.5	7.0	76.9	78.9	13.6	14.1
others	12.6	11.2	86.5	84.9	0.9	3.9

Source: MIP 1995, ZEW.

Appendix D: Reported barriers to innovation in East and West German firms

Which factors constitute barriers to innovative success, especially in East Germany? In the MIP survey firms are asked about the significance of 14 different barriers to innovation activity between 1990-1992 and 1992-1994, respectively. Three factors appearing to be of the most interest have been selected for the current paper: the lack of skilled workers, the lack of appropriate sources of finance and the legal restrictions (for a more extensive analysis of all barriers see Licht et. al. 1996). The results are presented in Table D. The percentage of firms which consider of the barriers as crucially significant is of main interest. The percentage of eastern firms regarding a barrier as crucial or very significant has developed similarly to West German firms during the observation period. The lack of skilled labour and legal restrictions have become less important, while the significance of the lack of appropriate sources of finance has increased.

However, quantitative differences in the change of the percentage of firms between the two periods can be observed. Whereas the share of eastern firms whose innovative activity has been hindered due to a lack of skilled workers totalled 39% (23% in West Germany) between 1990 and 1992, it fall by 21% below the corresponding share of firms in West Germany (28%). Legal restrictions are less important in East Germany, too. Conversely, the lack of appropriate sources of finance is a barrier for 50% of the firms in East Germany, compared to only 33% in West Germany.

Table D: The significance of innovation barriers (in % of all manufacturing firms)

significance	crucially/very significant		moderately significant		slightly significant/ insignificant	
period/region	East	West	East	West	East	West
			lack of skilled labour			
1990-1992	39.3	36.6	15.4	24.3	45.3	39.1
1992-1994	22.8	27.7	17.2	27.1	60	45.2
			legislation, norms, regulations, standards, taxation			
1990-1992	32.6	40.9	16.0	16.1	51.4	43.0
1992-1994	21.1	28.0	22.3	20.3	56.6	51.7
			lack of appropriate sources of finance			
1990-1992	48.6	28.2	19.6	20.3	31.8	51.5
1992-1994	49.8	33.2	14.9	18.9	35.3	47.9

Source: MIP 1993, 1995, ZEW.