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Employment Effects of Different Innovation Activities: Microeconometric Evidence

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Non-technical Summary

The relationship between technological change and employment has been controversially discussed for a long time. But, on the basis of the persistently high rate of unemployment in several Western European countries, innovation is still a key issue in the current debates on employment creation. From a theoretical point of view the effects of innovation on employment are not clearly determined. There are several mechanisms through which innovations can destroy existing jobs or create new ones (displacement versus compensation effects). The overall impact depends on a number of firm-, sector- as well as country-specific factors. Thus, the empirical answer to this long-standing question is more topical than ever.

Using the theoretical, multi-product framework recently proposed by Jaumandreu (2003), this paper reports new results on the relationship between the growth rate in total employment and innovation activities for German manufacturing firms. Furthermore, it is the first to provide empirical evidence for German service firms. The data set used is derived from the third Community Innovation Surveys (CIS 3) launched in 2001 and includes information on more than 2,200 German manufacturing and service sector firms observed in the period 1998-2000. The model establishes a link between the employment growth rate and the innovation output in terms of sales growth stemming from innovative products and process innovations. It allows to disentangle some of the theoretical employment effects and is highly applicable in analysing firm-level employment impacts of innovation activities using the specific information provided by CIS data.

Although employment effects are likely to differ according to the type of innovation, there is still a dearth of studies that focus on different innovation output indicators at the firm level. Using the above-mentioned new model framework, I am therefore extending the analysis in a second step by distinguishing between (i) two different product innovations according to their novelty degree (sales growth generated by market novelties and sales growth stemming from product innovations only new to the firm) and (ii) two different process innovation indicators (rationalisation and other process innovations respectively).

The econometric results confirm that successful product innovations have a positive impact on net employment at the level of the innovating firm. The impact tends to be larger in manufacturing firms than in the service sector, although the difference is statistically not significant. The results further provide evidence that the employment does grow one-for-one with the sales growth accounted for by new

products. In addition to that, the estimation results indicate that new jobs are not only created in firms launching market novelties, but also in firms which successfully pursue product imitation strategies. Moreover, the coefficients of both indicators of product innovation success were not significantly different. This holds for manufacturing and service firms. Hence, this result contradicts the hypothesis that employment effects depend on the degree of product novelty and stands in contrast to previous conclusions drawn by Falk (1999).

The impact of process innovations on employment growth turns out to be variable. In manufacturing firms, displacement effects outweigh compensation effects, resulting in a negative employment effect. But, as expected, the estimation results also reveal that not all process innovations are associated with employment reduction. Jobs are merely significantly deteriorated through rationalisation innovations, but not as a consequence of other process innovations. In contrast, process innovations are not responsible for a significant reduction in labour demand in service firms in the period 1998-2000.

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Abstract: Using the model recently developed by Jaumandreu (2003) this paper reports new results on the relationship between innovation and employment growth in Germany. The model is tailor-made for analysing firm-level employment effects of innovations using specific information provided by CIS data. It establishes a theoretical link between employment growth and innovation output. The econometric analysis confirms that product innovations have a positive impact on employment. In contrast to previous studies, this effect is independent of the novelty degree. Moreover, different employment effects between manufacturing and service firms regarding process innovations were found. Finally, from a cross country perspective the results for Germany are similar to those found for Spain and the UK.

Keywords: Innovation, employment, applied econometrics, manufacturing, services

JEL Classification: O33, J23, C21, O32, L60

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1 Introduction

The debate on the relationship between technological change and employment is an old one.[1] From a theoretical viewpoint there are different channels through which innovations can destroy existing jobs (displacement effects), but there also exist several mechanisms through which innovations may create new jobs (compensation effects). And the overall impact depends on a number of firm-, sector- as well as country-specific factors.

The empirical answer to this long-standing question is more topical than ever. This is based on the incessantly high rate of unemployment in Germany, but also in several other Western European countries. High unemployment induces severe problems such as those facing the German social security system or public budgets. In addition to an economic recovery, politics hope that innovations could provide an important contribution to strengthen the competitiveness of firms and consequently to the preservation or creation of new jobs.

This paper reports new results on the relationship between innovation and employment growth for German manufacturing firms and – to the best of my knowledge – is the first to provide empirical evidence for German service firms, using data from the third Community Innovation Surveys (CIS 3). The sample includes data on more than 2,200 German manufacturing and service sector firms observed in the period 1998-2000. Recently, Jaumandreu (2003) proposed a new model well-suited for analysing the employment impacts of innovations using the specific information provided by CIS data and estimated the model for Spanish firms. One interesting aspect of the approach is that it establishes a theoretical link between the employment growth and the innovation output in terms of the sales growth generated by new products as well as efficiency gains attributable to process innovations. A second notable feature shown here is that the CIS data are harmonised for the European countries included and thus allow firm-level cross-country comparisons. Hence, I use the same econometric model, the same estimation method and, last but not least, the internationally fully comparable German CIS data in the first part of this study.

In the second part, further insights into the innovation-employment nexus are gained by considering different types of product as well as process innovations, as employment effects are expected to differ according to the type of innovation. In case of product innovations, they are likely to depend on the product novelty degree. Falk (1999) has found evidence that new jobs are mainly created in firms

[1] For a historical overview see Petit (1995) or Freeman and Soete (1997).

that have positioned themselves on the cutting edge by launching products that are new to the market ("market novelties"), while no significant employment effects can be found in enterprises pursuing an imitation (follower) strategy. That is, in firms which offer new products that are new to the firm, but not new to the market ("firm novelties"). However, the latter firms are important for the diffusion of new technologies and the structural change within an economy. Moreover, most theoretical as well as empirical studies assume that process innovations work on the supply side by reducing unit cost. However, firms introduce new production technologies for a number of different reasons: rationalisation, improvement of product quality, or legal requirements, for instance. Displacement effects are assumed to be stronger for firms which introduce new processes for rationalisation reasons. Despite the large body of empirical work discussing the innovation-employment link, there is still a dearth of studies that focus on different innovation indicators at the firm level. Using the above-mentioned model framework, I am therefore extending the analysis by distinguishing between (i) two different product innovations according to their novelty degree (sales growth generated by market novelties and sales growth stemming from product innovations only new to the firm) and (ii) two different process innovation indicators (rationalisation and other process innovations respectively).

Four questions are addressed in the paper:

1. Do product and process innovations spur or diminish employment at the level of the innovating firm in Germany?
2. Do firm-level employment effects differ between products new to the firm and those new to the market?
3. Do employment effects differ between different kinds of process innovations?
4. Can one perceive a pattern common to industry and service firms regarding this topic?

The outline of the paper is as follows: Section 2 sketches some theoretical considerations about the channels through which innovations affect employment and section 3 summarises the main empirical firm-level results so far. The empirical model is explored in section 4. Section 5 describes the data set used for the empirical analysis and holds some descriptive statistics. The econometric results are presented in section 6. And finally, section 7 draws some conclusions on the relation between innovation and employment growth.

2 Theoretical Considerations

From a theoretical viewpoint, the impact of innovation activities on employment is not clearly determined. There are different channels through which technological change can destroy or create new labour: the overall impact depends on several factors and might differ in short- and long-run perspectives. First of all, it depends on the existing production technology and the nature of the technological progress itself, i.e., the type (product or process innovation), direction (labour- or capital-saving, neutral, skill-biased etc.), dimension (radical or incremental innovation) and manifestation (disembodied or factor-embodied) of the technological change. Moreover, consumer preferences, the competition on commodity and labour markets and the qualification structure of the labour force are of importance to the employment impact. The link between innovation and employment can be analysed on different levels: firm, sector and aggregate level. The following empirical analysis is restricted to employment effects at the level of the innovating firm, as one of the main instances where these mechanisms are supposed to work more or less explicitly are at the firm level. On a sector or aggregate level, technological progress is associated with further impacts on firms' labour demand, which cannot be taken into account in the present study.

Both product and process innovations influence employment via different channels; see, e.g., Stoneman (1983), Katsoulacos (1984) or Blechinger et al. (1998):

If process innovations lead to an increase in productivity, firms are able to produce the same amount of output with less input and ceteris paribus lower costs. The immediate extent of the employment effect in the innovating firm depends on the current production technology and thus the substitutability between input factors, as well as on the direction of the technological change. As a rule, this negatively affects employment in the short run and is thus called the displacement effect of process innovations. At the same time, the innovative firm can pass on the cost reduction to output prices which results – in a dynamic perspective – in a higher demand for and output of the product. This effect depends on the amount of price reduction, the price elasticity of demand and the degree of competition. The more intense the competition on the commodity market, the higher the extent to which cost reductions are passed to output prices. This mechanism enhances labour demand (compensation effect), and thus the overall employment change at the level of the innovating firm is not clear. Additional employment effects may occur in upstream or downstream firms, e.g., if the innovative firm is able to increase its output, its suppliers also benefit and may boost their labour demand. On the other hand, competitors which cannot keep pace with the technological progress will lose market share or even disappear, implying a deterioration of jobs in those firms. Furthermore, the competition on commodity and labour markets have to be taken into account when analysing employment effects on a sector or aggregate level.

If a new product has successfully been launched to the market, it creates new demand for the firm. The demand effect is likely to be the result of a market expansion as well as a business-stealing effect. As a consequence, product innovations increase the labour demand of the innovating firm (compensation effect, which is also called positive direct effect). The amount and sustainability of compensation effects resulting from demand increases depend on the competition and the delay with which competitors react (see Garcia et al. 2002). If the innovating firm produces more than one good, the amount also depends on synergies in production. The higher synergy effects are, the lower, ceteris paribus, the effect on labour demand is, as common production implies economies in input factors. Additionally, indirect employment effects occur which depend on the substitutability between the old and new products. If the new product (partially or totally) replaces the old one, labour demand for the old product will decrease and the overall effect is again not clear for the innovating firm. However, if both products are complements, employment will increase.

Employment effects of product innovations are also likely to depend on the product novelty degree. From a theoretical point of view, the product life cycle theory of Vernon (1966), which states that each product or sector follows a life cycle, provides one explanation. By definition, market novelties initiate the cycle of the product or even the sector. According to this theory, younger sectors are less mature as consumers are not yet well equipped and thus, they experience higher demand increases (see Greenan and Guellec 2000). As a consequence, market novelties should, ceteris paribus, result in higher output and employment growth.

On the other hand, firms develop innovations to alter market structures and to reduce the competitive pressure. This intended change is an important incentive for innovation activities. If firms are successful, i.e., if the own price elasticity for their commodity is diminished, then product innovations should, ceteris paribus, result in higher prices and decreasing output and employment (see, e.g., Smolny 1998). This effect should be more pronounced in case of market novelties as they define an at least temporary monopoly. Moreover, market novelties are usually associated with a higher uncertainty and a higher risk of failure which might also lead to a lower employment growth.

3 Previous Empirical Findings

The large body of empirical work discussing the innovation-employment link has concentrated on two major questions: The first one is related to the impact of technological change on total employment, mainly on aggregate or industry level, but there is also a growing number of firm-level studies. The second strand of empirical literature focuses on the question whether innovation activities induce a change in the skill structure of employees, referred to as the technological skill bias, as it is hypothesised that technological changes increase the demand for high skilled labour and reduce that for low skilled persons.[2] In what follows, only studies dealing with the first question will be taken into account. For an overview of empirical studies on technological skill bias, see, e.g., Chennels and Van Reenen (1999) or Kaiser (2000, 2001) and Falk and Seim (2000, 2001) and the references cited therein.

For a long time, empirical innovation research has focused on input-oriented innovation indicators when measuring aspects of innovation, i.e., mainly productivity but also employment effects (see, e.g., Griliches 1995). This means that, traditionally, conditional labour demand functions are estimated using factor prices, output and a measure of innovation input (like R&D capital stock, R&D expenditure or IT investment) as explanatory variables. However, the innovation input transforms into product as well as process innovations and both affect labour demand via different channels. In the nineties the focus changed to more output-oriented innovation indicators.[3] One obvious reason for this trend is connected to the greater availability of large firm data bases and especially the development of the Oslo Manual (OECD and Eurostat 1992, 1997) and the release of new, internationally harmonised survey data, known as the Community Innovation Surveys (CIS), which began in the first half of the 1990s. The Oslo Manual gives a unique definition of innovation and innovation output.

Reviewing previous econometric firm-level studies which explicitly focused on the distinction between employment impacts of product and process innovations, we can ascertain that the majority of them have found a stimulating effect of product innovations on labour demand in manufacturing. For Western Germany, this was shown in the studies of Entorf and Pohlmeier (1990), König et al. (1995), Blechinger

[2] Closely related to the aspect of the shift in the labour demand from low to high skilled personnel is the increasing inequality of the relative wages across skill groups; see, e.g., Fitzenberger (1999).

[3] Traditionally, patents have been used as an indicator to measure innovation output. However, patent-based indicators have been heavily criticised as being a poor measure of innovative outcome (see Griliches 1990).

et al. (1998), Rottmann and Ruschinski (1998) or Smolny (1998, 2002).[4] The same qualitative result was confirmed by Van Reenen (1997) for the UK, by Garcia et al. (2002) for Spain or by Greenan and Guellec (2000) for France.

As Falk (1999) pointed out, this effect depends on the novelty degree. Using German CIS 2 manufacturing data covering the period 1994-1996 he showed that firms launching market novelties expected an increase in labour demand. Contrarily, no significant employment effects were found in enterprises which had solely launched imitative products that are new to their own firm, but not to the market. However, Falk (1999) analysed the expected instead of the realised employment change. Brouwer et al. (1993) found that firms with a high share of product-related R&D experienced an above average growth of employment. They interpret their innovation indicator as a proxy of R&D related to industrial activities in an early stage of the life cycle. All in all, there is currently little empirical evidence of how employment effects depend on the degree of product novelty.

Moreover, there is no clear evidence of a robust effect of process innovations on jobs in manufacturing. In the studies of Van Reenen (1997) and Entorf and Pohlmeier (1990) the impact of process innovations turned out to be small and not significant at all, while König et al. (1995), Smolny and Schneeweis (1999), Smolny (2002) or Greenan and Guellec (2000) reported that process innovators experienced significantly higher employment growth rates. The latter study even found evidence that process innovations, compared to product innovations, are of greater importance to create new employment at the firm level.[5] Contrarily, Blechinger et al. (1998) found evidence that the introduction of new production technologies led to a reduction in employment in manufacturing firms in Western Germany in the mid nineties - the effect being more pronounced in larger firms.

With the exception of Van Reenen (1997), who used the number of major innovations, the above mentioned studies estimated reduced form equations including dummy variables for product and process innovations.

So far, there is hardly any econometric evidence on the overall employment effects of technological change for service firms, Jaumandreu (2003) being an exception. Using the model described in the next section, he found some indication that the net outcome of process innovation was employment displacement in the Spanish service sector, although the effect was not significant. Like in manufacturing, product innovations were associated with employment growth.

[4] The result of Zimmermann (1991) is an exception.

[5] However, the reverse relationship was detected on the sectoral level.

4 Model

The model developed by Jaumandreu (2003) allows to disentangle some of the theoretical employment effects mentioned above and is highly applicable in analysing firm-level employment impacts of innovation activities using the specific information provided by CIS data. The share of sales due to product innovations serves as the key output indicator in this data. One interesting aspect of the approach is that it establishes a theoretical relationship between employment growth and results of innovation activities at the firm level. That is, it postulates a link between the employment growth rate and the innovation output in terms of sales growth stemming from innovative products. The latter can be directly calculated by means of CIS data.

4.1 Basic Model

The model is based on the idea that firms can produce different products. At the beginning of the reference period, a firm i produces one or more products which are aggregated to one product and the corresponding output is Y_{i1}. In what follows, this aggregate product is called the "old product". In the period under consideration, the firm can decide to launch one or more new (or significantly improved) products, with the aggregate output of the new products at the end of the reference period being Y_{i2}. We assume in the remainder of the text that the innovation decision is predetermined to the employment decision, i.e., we do not model the firm's choice to innovate or not.[6] The new product can (partially or totally) replace the old one if they are substitutes, or enhance the demand of the old product if complementarity exists. Thus, in the same period, the output of the unchanged product increases or declines by $\triangle Y_{i1}$.[7]

To produce the different outputs, it is assumed that firms must replicate the conventional inputs labour L_i and capital C_i and that the production function F is linear-homogeneous in these conventional inputs. To keep the model as simple as

[6] The possible simultaneous determination of innovation and employment might induce an endogeneity problem in the estimation.

[7] This set-up does not mean that the model is only restricted to firms that change their status from non-innovator to innovator. The label "old product" is justified viewed from the end of the reference period (here, the reference period is 1998-2000), because the OSLO Manual defines innovators as enterprises that have successfully completed at least one innovative project within a three-year period. That is, new products introduced, for example by firm i in 1997 define said firm as an innovator at the beginning of the reference period in 1998, but are not viewed as innovations in 2000 any longer.

possible, we assume that labour is a homogenous input factor. However, a knowledge capital exists which is a non-rival input to the production processes, and which drives specific efficiencies for each process and its evolution over time. Assuming that (i) knowledge proportionally raises the marginal productivity of all conventional inputs by an efficiency parameter θ_j, for $j = 1, 2$, (ii) the efficiency in the productive process for the old product can increase by $\triangle\theta_1$, e.g. due to process innovations, learning effects or exogenous technological progress, and (iii) economies of scope are absent, this leads to the following equations (1) and (2) for the old product's output Y_i at the beginning and the end of the reference period, respectively:

$$Y_{i1} = \theta_1 \cdot F\left(L_{i1}, C_{i1}\right) \qquad \forall\, i \qquad \text{and} \tag{1}$$

$$Y_{i1} + \triangle Y_{i1} = \left(\theta_1 + \triangle\theta_1\right) \cdot F\left(L_{i1} + \triangle L_{i1}, C_{i1} + \triangle C_{i1}\right) \qquad \forall\, i. \tag{2}$$

The corresponding end-of-period output of the new product is given by (3):

$$Y_{i2} = \theta_2 \cdot F\left(L_{i2}, C_{i2}\right) \qquad \forall\, i. \tag{3}$$

According to the duality theorem and the assumptions of linear-homogeneity and separability, these production functions correspond to the cost function:

$$C_i^* = \begin{cases} c\left(w_i, r_i\right) \cdot \frac{Y_{i1}}{\theta_1} & \text{at the beginning of the period} \\ c\left(w_i, r_i\right) \cdot \frac{Y_{i1} + \triangle Y_{i1}}{\theta_1 + \triangle\theta_1} + c\left(w_i, r_i\right) \cdot \frac{Y_{i2}}{\theta_2} & \text{at the end of the period} \end{cases} \tag{4}$$

with the input prices wage w and interest rate r and $c\left(.\right)$ stands for marginal costs. Denoting $c_L\left(w_i, r_i\right) = \partial c\left(w_i, r_i\right) / \partial w_i$ and applying Shephard's Lemma we can derive the labour demand functions for the different products for each period. Assuming that the input prices are constant, the labour demand for product 1 and thus the firm's overall employment at the beginning of the reference period is (for ease of presentation, firm indices i are suppressed in the following terms) $L_1 = c_L \cdot \left(Y_1/\theta_1\right)$. At the end of the period, firm i demands $L_1 + \triangle L_1 = c_L \cdot \left[\left(Y_1 + \triangle Y_1\right) / \left(\theta_1 + \triangle\theta_1\right)\right]$ for the old and $L_2 = c_L \cdot \left(Y_2/\theta_2\right)$ for the new product. Thus, the employment growth is given by equation (5):

$$\frac{\triangle L}{L} = \frac{\triangle L_1 + L_2}{L_1} = \frac{c_L \cdot \left(\frac{Y_1 + \triangle Y_1}{\theta_1 + \triangle\theta_1}\right) - c_L \cdot \left(\frac{Y_1}{\theta_1}\right) + c_L \cdot \left(\frac{Y_2}{\theta_2}\right)}{c_L \cdot \left(\frac{Y_1}{\theta_1}\right)}, \tag{5}$$

which can be rearranged to

$$\frac{\triangle L}{L} = \left(\frac{Y_1+\triangle Y_1}{\theta_1+\triangle\theta_1}\right)\cdot\frac{\theta_1}{Y_1}-1+\frac{\theta_1}{\theta_2}\cdot\frac{Y_2}{Y_1}. \tag{6}$$

Using a first order (linear) approximation for the first fraction, employment growth can be written as

$$\frac{\triangle L}{L} \simeq \frac{-\triangle\theta_1}{\theta_1}+\frac{\triangle Y_1}{Y_1}+\frac{\theta_1}{\theta_2}\cdot\frac{Y_2}{Y_1}. \tag{7}$$

According to equation (7), employment growth stems from three different well-known sources: (i) from the efficiency increase in the production of the old product, which negatively affects labour demand; (ii) from the rate of change in the production of the old product (which is provoked by the new product to a certain degree, the induced change being negative for substitutes and positive for complements); and (iii) from starting production of the new product (positive sign). The employment effect of the latter depends on the efficiency ratio between both production technologies.

Transforming the economic model in an econometric model and taking into account that efficiency gains are likely to be different between process innovators and non-process innovators, we arrive at equation (8):

$$l = \alpha_0+\alpha_1\, d+y_1+\beta y_2+u \tag{8}$$

with

l	:	employment growth rate
α_0	:	(negative) average efficiency growth for non-process innovators
α_1	:	average efficiency growth for process innovators
d	:	dummy variable indicating process innovations
y_1	:	real output growth due to old products $\frac{\triangle Y_1}{Y_1}$
y_2	:	real output growth due to new products $\frac{Y_2}{Y_1}$
u	:	error term with $E\,(u\,\vert\,d,y_1,y_2)=0$

Equation (8) implies that even non-process innovators can achieve efficiency gains, possibly due to exogenous technological progress, organisational changes, improvements in human capital, learning or spill-over effects.

One problem in estimating equation (8) is that we do not observe real output growth but nominal sales growth. However, we can split the firm's (observed) sales growth rate into the sales growth due to old (g_1) and new products (g_2) and using the following definitions we can derive equation (10) in nominal variables, which serves as the basic estimation equation. Concerning the nominal rate of sales growth due to old products, the relation $g_1 = y_1 + \pi_1$ holds approximately, where p_1 is the price of the old product at the beginning of the reference period and π_1 represents the corresponding inflation rate over the period. g_2 is defined as the ratio of sales of new products to sales of old products measured at the beginning of the period:

$$g_2 = \frac{p_2\,Y_2}{p_1\,Y_1} = y_2 + \pi_2\,y_2 \quad \text{with } \pi_2 = \frac{p_2 - p_1}{p_1} \tag{9}$$

This leads to the following estimation equation[8] :

$$l - g_1 = \alpha_0 + \alpha_1\,d + \beta\,g_2 + v \tag{10}$$

with

$g_1 = y_1 + \pi_1$	:	nominal rate of sales growth due to old products
$g_2 = \frac{p_2\,Y_2}{p_1\,Y_1} = y_2 + \pi_2 y_2$	:	sales ratio of new to old products
π_1	:	price growth of old products
π_2	:	ratio of the price difference between the new and old products to the price of the old product
$v = -\pi_1 - \beta\pi_2 y_2 + u$	:	error term,

where we assume that $E(\pi_2|y_2) = 0$. Then $E(\pi_2 y_2) = 0$ and $\pi_2 y_2$ is uncorrelated with y_2.

Note that $l - g_1$ is used as right-hand variable as new products cannibalise the old ones to some extent and are thus to a certain degree responsible for the old products' change in sales. This implies that we are estimating a net employment effect.

As mentioned by Jaumandreu (2003), the relationship (10) implies endogeneity as well as identification problems for the estimation. The endogeneity problem occurs because, by definition, g_2 is correlated with the error term v. The identification problem results from the fact that we cannot observe firm-level price changes, which leads to π_1 being included in the error term. As a consequence, it is not possible

[8] If the inflation rate π_1 has a non-zero mean, one could include $-E(\pi_1)$ in the intercept and $-(\pi_1 - E(\pi_1))$ in the error term.

to identify the gross employment effect of efficiency (productivity) gains but merely the net employment effect which has been accounted for indirect price effects. If efficiency rises by the factor a, marginal costs decline by the same factor. Depending on competition and market power, firm i passes on the cost reduction to its clients by the factor δ so that the price is reduced by δa. As long as we cannot control for firm-level price changes of the unchanged product, we are only able to estimate the net effect $-a - \pi_1 = -(1-\delta)a$. To overcome this hindrance, Jaumandreu (2003) proposed to use the disaggregate price indices $\widetilde{\pi}_1$ and $l - (g_1 - \widetilde{\pi}_1)$ as dependent variable (see also footnote 8). This method leads to an identification of the average gross productivity effect if firms behave according to the sector average. However, the identification problem is still valid for firms that deviate from the average price behaviour. In the empirical analysis, I will rely on equation (10), using $l - g_1$ or $l - (g_1 - \widetilde{\pi}_1)$ as dependent variable in a first step.

4.2 Extended Model

It is expected that employment effects may not only depend on the type (product or process) but also on the dimension of technological change. Therefore, the analysis is simply broadened in a second step by distinguishing between different kinds of product as well as process innovations.

I use the the above mentioned multi-product framework and assume that, depending on its innovation strategy, firm i decides upon the product novelty degree by launching new products that are new to the market ("market novelties") and/or by introducing products which are new to the own firm, but not to its relevant market ("firm novelties"), with the aggregate output of the respective products at the end of the reference period being Y_{i2m} and Y_{i2f}.[9]

Most theoretical as well as empirical studies assume that process innovations reduce unit cost. However, the introduction of new production technologies may have several different purposes. Process innovations may aim to improve the quality of products or to assure that products or production processes meet new legal requirements; firms also introduce new technologies simply to be able to produce a new product. Last but not least, process innovations may be intended to rationalise in terms of reducing average production costs. I allow for the fact, that efficiency and thus employment effects may differ according to the type of process innovation. It

[9] The innovation decision is still assumed to be predetermined.

is assumed that the displacement effects are higher for firms with rationalisation innovations.

Both considerations lead to the following estimation equation in the second step:

$$l - g_1 - \widetilde{\pi}_1 = \alpha_0 + \alpha_c\, d_c + \alpha_{nc}\, d_{nc} + \beta_m\, g_{2m} + \beta_f\, g_{2f} + v \qquad (11)$$

with g_{2m} and g_{2f} denoting the sales growth generated by market novelties and firm novelties respectively and d_c meaning a rationalisation innovation and d_{nc} other process innovations. The hypothesised relationship is $\alpha_c < \alpha_{nc}$, because we expect that the displacement effects are higher for firms with rationalisation innovations. As was set forth in section 2 the employment consequences of introducing new products are likely to depend on the product novelty degree. But from a theoretical point of view, the expected relationship between β_m and β_f is ambiguous.

5 Data Set and Descriptive Statistics

The data set used is based on the 2001 official innovation survey in the German manufacturing and service industries, which was the German part of the Community Innovation Surveys CIS 3.[10] Firms were observed for the reference period 1998-2000. The survey collected data on 4,611 firms, 1,922 of which are in manufacturing (NACE 15-37), 2,433 in services (NACE 50-90) and the rest in mining, quarrying, electricity, gas and water supply and construction. In Germany, the innovation survey covers firms with at least 5 employees, but to facilitate comparison of my results with those of Jaumandreu (2003), I include only firms with 10 or more employees.[11] Furthermore, I restrict the sample to manufacturing and to those service sectors which are covered by CIS 3, i.e., wholesale trade (NACE 51), transport/storage (60-63), post and telecommunication (64), financial intermediation (65-67), computers and related activities (72), research & development (73) and technical services (74.2+74.3).

For estimation purposes, I further exclude (i) firms established during 1998-2000 (i.e., if employment or sales are zero or missing for 1998) and (ii) firms which experience an increase or decrease in turnover of more than 10 per cent due to mergers

[10] A more detailed data description is given in the appendix.

[11] However, estimations for the whole sample, including firms with at least 5 employees, show that the results do not substantially differ from those reported for the restricted sample. These estimation results are available on request.

or due to the sale or closure of a part of the enterprise. Besides that, a few outliers (in which employment growth or labour productivity growth turned out to be higher than 300 per cent) were eliminated and firms with incomplete data for all relevant variables were dropped. The total number of observations remaining for the empirical analysis is 1,319 for manufacturing and 849 for services. An overview of the sectors and the distribution of innovating and non-innovating firms is given in table 8 in the appendix. Table 9 contains information on the distribution by size classes.

To compute price growth rates, I use producer price indices on a 3-digit NACE level for manufacturing. For a few 3-digit NACE classes no indices are published; here, the producer price indices on the corresponding 2-digit NACE level are used as proxy.[12] For service firms, I am only able to apply 7 different price indices.[13] All indices are elaborated and published by the German Statistical Office (Destatis).

The descriptive statistics displayed in table 3 show the growth rates of employment, sales and prices of the sampled firms in the period 1998-2000. Additionally, table 4 introduces the means and standard deviations for other major innovation variables used in the study (see tables 11 and 12 in the appendix for a detailed definition and calculation of all variables).

[12] In Germany, producer price indices are available for 87 3-digit NACE classes in manufacturing. However, no producer price indices are published for the classes 17.3, 18.3, 20.5, 21.1, 22.3, 23.3, 28.5, 28.6, 29.6, 33.3, 35.3, 35.4, 35.5, 37.1, 37.2.

[13] Producer price indices are available for wholesale trade, shipping and air as well as railway transport, which were applied for NACE 51, 61, 62 and 60.1. For NACE 60 (except 60.1) and 63 I use the transport component of the consumer price index, for 64 the corresponding telecommunication component. For all other service sectors, price growth rates are computed from the services component of the consumer price index.

Table 1: **Employment and Sales Growth Rates for Innovators and Non-innovators, 1998-2000.**

Firm type	Employment growth			Sales growth															Price growth		
				Total			Old product			New product											
										Total			Firm novelty			Market novelty					
	m	s.d.	med	m	s.d.	med	m	s.d.	med	m	s.d.	med	m	s.d.	med	m	s.d.	med	m	s.d.	med
Manufact.																					
Non-innov.	2.4	20.0	0.0	10.8	31.2	6.0	10.8	31.2	6.0	–	–	–	–	–	–	–	–	–	1.1	4.8	1.2
Pc only	6.0	22.7	2.3	21.7	44.1	11.4	21.7	44.1	11.4	–	–	–	–	–	–	–	–	–	2.4	7.0	1.6
Pd only	8.1	28.2	2.6	15.2	31.8	8.7	−18.4	31.5	−16.1	33.6	35.1	22.6	21.6	25.8	12.6	12.0	23.6	4.3	1.4	5.5	1.8
Pd & pc	9.4	28.2	4.1	19.3	36.0	12.5	−15.9	34.0	−13.9	35.2	35.5	25.3	21.2	23.6	14.8	14.0	28.7	5.6	1.2	3.4	1.8
Total	5.9	24.7	1.6	15.2	34.4	8.7	−1.5	36.9	−1.2	16.7	30.0	0.0	10.3	20.2	0.0	6.4	19.6	0.0	1.3	4.9	1.7
Services																					
Non-innov.	5.9	33.7	0.0	14.4	52.8	4.6	14.4	52.8	4.6	–	–	–	–	–	–	–	–	–	5.0	5.8	4.2
Pc only	6.1	28.8	0.0	11.2	32.6	5.4	11.2	32.6	5.4	–	–	–	–	–	–	–	–	–	4.7	5.8	1.8
Pd only	17.9	34.3	8.8	25.8	55.8	12.5	−11.3	49.2	−11.9	37.2	42.4	23.0	22.1	31.9	10.1	15.1	29.1	6.6	3.2	3.1	1.8
Pd & pc	16.1	38.9	5.9	25.4	48.1	13.4	−19.6	39.6	−11.6	45.0	52.8	25.7	27.5	36.9	15.9	17.5	37.4	5.7	2.8	2.8	1.8
Total	10.2	34.9	0.0	18.5	51.0	8.0	2.2	50.1	0.0	16.3	36.5	0.0	9.9	25.0	0.0	6.5	22.7	0.0	4.2	5.0	1.8

Notes: Rates of growth for the entire period 1998-2000. Entrants and firms affected by merger, sale or closure are excluded, as are firms with less than 10 employees in 2000 or those lacking complete information.

Some interesting similarities and differences between the two total samples (i.e., samples including both innovative and non-innovative firms) for manufacturing and services are displayed. Starting with the differences, the average employment growth rate between 1998 and 2000 is nearly two times higher in the service sector (10.2) compared to the manufacturing sample (5.9). However, we find that in both sectors the average employment growth is higher in innovative firms. The average employment growth rates are higher than the official figures (labour force growth rate in Germany between 1998-2000: 4.7 per cent, i.e., average growth rate of 2.3 per cent p.a.; see http://www.destatis.de). But of course, these figures are not directly comparable due to (i) different calculation methods, (ii) the sample restriction and (iii) a selectivity problem. The latter is due to the fact that only surviving firms in 2000 are covered by the survey. However, the figures are consistent with the stylised fact that services in Germany have gained in importance since the mid eighties, and that employment shifts from manufacturing to the service sector (see Statistisches Bundesamt or Peters 2003). Similar differences between manufacturing and service firms can be found in sales and price growth rates. On average, nominal sales mounted by 15 per cent in manufacturing between 1998 and 2000, while prices increased by 1.3 percent. The corresponding figures for services are 18 and 4 per cent. However, this implies that real sales grew roughly by 7 per cent p.a. in both sectors.

About 60 per cent of the manufacturing enterprises introduced at least one product or process innovation in the reference period, compared to only 50 per cent of the service firms. New products were launched by 48 per cent of all firms in manufacturing. In the service sector just 40 per cent of the enterprises supplied new services to their clients. However, in both samples two out of three product innovators launched at least one market novelty. Process innovations are less common with 38 and 31 per cent in manufacturing and services, respectively. The German CIS data set provides an additional distinction between firms applying rationalisation innovations and those utilising other process innovations. Just 26 per cent of all manufacturing firms, that is nearly three out of four process innovators, introduced new production technologies to rationalise processes. However, amongst service sector firms only one half of all process innovators experienced cost reductions due to new processes. In both sectors nearly one half (45 %) of all innovative firms introduced new products as well as new production technologies, while amongst the other half, one third concentrated solely on process innovation and the remaining two thirds on pure product innovation activities.

Looking at the innovation performance, we find that in both sectors innovative firms earned approximately 25 per cent of their turnover in 2000 with product in-

Table 2: **Descriptive Statistics for Total and Innovative Sample.**

	Manufacturing				Services			
	Total sample		Innovative sample[a]		Total sample		Innovative sample[a]	
	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
Quantitative variables								
Employment	275	1168	389	1506	531	8044	990	11515
Employment growth	5.9	24.7	8.4	27.3	10.2	34.9	14.9	35.7
Sales growth	15.2	34.4	18.2	36.2	18.5	51.0	22.8	48.9
Investment growth	17.8	97.4	15.9	92.1	18.2	96.7	14.3	88.6
Innovation expenditure[b]	–		6.3	8.8	–		10.7	20.2
R&D expenditure[b]	–		2.7	4.9	–		6.0	14.1
Sales with new products[b]	–		23.5	23.4	–		25.0	27.7
Sales with market novelties[b]	–		8.5	14.9	–		9.3	16.2
Sales with firm novelties[b]	–		14.9	19.1	–		15.7	22.8
Qualitative variables[c]								
Innovator	58.5	0.493	100.0	0.0	48.6	0.500	100.0	0.0
Product	48.4	0.499	82.6	0.379	39.3	0.488	80.8	0.394
Market novelty	31.8	0.465	54.3	0.498	24.8	0.432	51.1	0.500
Process	37.5	0.484	641	0.478	30.9	0.463	63.6	0.482
Rationalisation	27.0	0.444	46.1	0.499	16.4	0.371	33.9	0.474
R&D	38.5	0.489	61.2	0.486	25.9	0.438	48.4	0.500
Patents	26.5	0.444	39.9	0.490	9.9	0.300	18.2	0.386
Effect: range	48.9	0.500	78.5	0.411	39.5	0.389	76.3	0.426
Effect: quality	52.2	0.499	83.8	0.368	43.2	0.496	81.6	0.388
Effect: market	44.9	0.498	72.0	0.449	32.8	0.470	61.7	0.487
Source: clients	46.8	0.499	73.2	0.443	33.6	0.473	60.8	0.489
Source: science	7.7	0.266	12.0	0.325	6.7	0.250	13.1	0.338
No. of observations	1319		772		849		413	

Notes: ([a]) Innovative firms are defined as firms with product and/or process innovations. ([b]) As percentage share of sales in year 2000 and ([c]) as share of firms.

novations introduced during 1998-2000, including about 9 per cent with market novelties. This corresponds to a sales growth rate due to product innovations of nearly 35 per cent in manufacturing: 33.6 per cent for firms only launching new products and 35.2 per cent for firms introducing both new products and processes. In the service sector these growth rates are even a little higher, at 37 and 45 per cent, respectively. In both sectors, firm novelties contributed more to sales growth than market novelties. At the same time, sales for old products decreased substantially for product innovators, revealing that the new products replaced the old ones to a large extent. All in all, this induced the sales growth rate of product innovators to be roughly 11 and 14 percentage points higher than that of non-innovative firms or pure process innovators in the service sector. Note that the German economy experienced a considerable upswing in economic activity during this period, the peak being in the year 2000.

6 Empirical Analysis

6.1 Estimation Procedure

As mentioned above, the relationship (10) implies an identification and an endogeneity problem. Columns 2 and 3 of tables 3 and 4 display estimates for the dependent variable in nominal terms, i.e. total employment growth minus growth of sales due to old products, $l - g_1$. We use this definition because new products are to some extent substitutes for the old products and are thus, to a certain degree, responsible for the old products' change in sales. This implies that we are estimating a net employment effect. To address the identification problem, industry price growth rates were additionally subtracted in all other estimations (i.e., $l - (g_1 - \widetilde{\pi}_1)$ was used as the dependent variable).[14]

Due to the likely endogeneity problem, applying OLS to equation (10) would yield inconsistent parameter estimates.[15] Hence, the model is estimated applying the instrumental variable (IV) method. Instruments for the endogenous right-hand-side variable *sales growth due to new products* should be correlated with the real rate of sales growth stemming from innovations, but should be uncorrelated with the change in relative prices. The success of product innovations in terms of sales growth are likely to be correlated to the following factors (the variables in parentheses are tried as instruments in the empirical analysis to measure these factors; see tables 11 and 12 for a more detailed definition):[16]

[14] This implies that the coefficient of the sales growth due to unchanged products is assumed to be 1. A more flexible alternative would be to estimate the coefficient of this variable, too, but this was not done here.

[15] The estimates for the coefficient of sales growth due to new products seemed to be downward biased; see column 2 in tables 3 and 4. The Durbin-Wu-Hausman (DWH) test confirmed the endogeneity problem and rejected the null hypothesis that the OLS estimator is consistent. The DHW test is based on an artificial regression by including the predicted value of the endogenous right-hand-side variable (as a function of all exogenous variables) in a regression of the original model and applying an F test for significance of the additional regressor, see Davidson and MacKinnon (1993). For example, using the instruments proposed in regression (2), the DWH statistic was 44.15 (p-value: 0.000) in manufacturing and 10.84 (0.001) in services; using the preferred instruments of regression (6) the corresponding figures were: 3.20 (0.074) and 7.27 (0.007).

[16] Factors which have been found to be important in explaining the success of product innovations in the theoretical as well as empirical literature are, among others: R&D and innovation input (Crepon et al. 1998, Lööf and Heshmati 2001, Love and Roper 2001 or Janz et al. 2004), technological opportunities (see Cohen and Levinthal 1989), technological capabilities (e.g., Dosi 1997 or König and Felder 1994), absorptive capacity (e.g., Becker and Peters 2000), market demand (Crepon et al. 1998), network relationships, especially with costumers (Hippel 1988 or Beise and Rammer 2003), corporate governance structure (Czarnitzki and Kraft 2004), or knowledge capital of employees, see Love and Roper (2001).

- innovation input (*R&D intensity*: ratio of R&D expenditure to sales or *innovation intensity*: ratio of innovation expenditure to sales),

- effects of product innovations (*range*: expansion of range of goods, *quality*: quality improvements or *market*: increase in market shares),

- degree of product novelty (*market novelty share*: share of sales due to market novelties; only applied in the basic model),

- appropriability conditions (*patent*: firms which applied for at least one patent),

- technological capabilities (*continuous R&D*: continuous engagement in intramural R&D activities),

- technological opportunities (*science*: universities, public or commercial research institutes are important sources of innovation),

- integration of costumers into the innovation process (*client*: costumers are important sources of innovation),

- competitiveness (*export extensity*: ratio of exports to sales or *export growth*: growth rate of exports).

However, it is not clear how these factors are linked to price changes, so instrument validity has to be checked which was done by performing the Sargan-Hansen overidentification test.[17] Additionally, subsets of instruments are tested using a "difference-in-Sargan" statistic, which is called the C statistic. The C statistic is defined as the difference of the Hansen statistics of the unrestricted equation (with the smaller set of instruments) and the restricted equation (with the larger set of instruments). Under the null hypothesis that both the restricted and unrestricted equations are well-specified, the C statistic is distributed as chi-squared in the number of instruments tested. The acceptance of the null, i.e., that the subset of orthogonality conditions is valid, requires that the full set of orthogonality conditions be valid (see e.g., Wooldridge 2002).

For Spanish firms, Jaumandreu (2003) proposed the variables *R&D intensity, range* and *market novelty share* as instruments. To compare results, in regressions (2)–(4) of tables 3 and 4 I used the same instruments. However, in several regressions

[17] It is well-known that the Sargan test statistic is not consistent if heteroskedasticity is present. This problem was addressed through the use of the heteroskedasticity-consistent Hansen statistic.

the test of overidentifying restrictions rejected the null hypothesis of valid instruments for the German data set. Using the difference-in-Sargan statistic, which allows a test of a subset of the orthogonality conditions (i.e., it is a test of the exogeneity of one or more instruments), I found that it is the *R&D intensity* which is often rejected as a valid instrument. In regression (5) the *innovation intensity* was used instead, but Hansen's J statistic again rejected the null hypothesis of the validity of the moment restrictions. After testing the different above-mentioned instruments, *continuous R&D, patent, client, science* and, in addition, *range* in manufacturing were used as instruments in estimation (6) of tables 3 and 4 and in all estimations of tables 5 and 6. Using this set of instruments, the null hypothesis regarding the validity of the orthogonal restrictions was accepted for all estimations. The interpretation of the results in section 6.2 is mainly based on this preferred set of instruments.[18]

The conventional IV estimator, though consistent, is, however, inefficient if heteroskedasticity is present. When facing heteroskedasticity of unknown form, efficient estimates can be obtained by applying General Method of Moments (GMM) techniques. I test the null hypothesis of homoskedasticity performing the test proposed by Pagan and Hall (1983), see also Baum et al. (2003). Using two different sets of indicator variables that are hypothesized to be related to the heteroskedasticity (levels, squares and cross-products or levels only of the instruments), both statistics PH_{all} and PH_{lev} did not reject the null hypothesis of homoskedasticity. Thus, IV was considered as appropriate method.[19]

6.2 Econometric Results

The empirical results revealing the relationship between employment growth and product and process innovations are reported in tables 3 and 5 for manufacturing and in 4 and 6 for services, respectively.

All in all, I arrive at plausible and, in the first part, very similar estimates for the employment effects of product innovations compared to the results for Spain, France and the UK; however, there are discernible differences concerning the impact of process innovations (see Jaumandreu 2003 and Harrison et al. 2004.)

The main result, which is quite robust to different specifications, is that successful product innovations have a significantly positive employment impact, i.e., the higher the sales growth rate due to product innovations, the higher the employment growth

[18] First-step regression results for this set of instruments are presented in table 10 in the appendix.

[19] GMM was applied in regression (7). The results are more or less the same compared to IV.

Table 3: **Effects of Product and Process Innovations on Employment for Manufacturing Firms, 1998-2000.**

Basic Model: $l - (g_1 - \widetilde{\pi}_1) = \alpha_0 + \alpha_1 \, d + \beta \, g_2 + v$

Dep. Variable	$l - g_1$		$l - (g_1 - \widetilde{\pi}_1)$				
Method	OLS	IV	IV	IV	IV	IV	GMM
Regression	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Expl. Variables	coeff. (t-stat)	coeff. (t-stat)	coeff. (t-stat)	coeff. (t-stat)	coeff. (t-stat)	coeff. (t-stat)	coeff. (t-stat)
Constant	−6.759	−8.851	−7.605	−6.059	−6.053	−5.773	−5.766
	(−6.14)	(−7.04)	(−6.03)	(−3.71)	(−3.71)	(−3.64)	(−3.65)
Process	−1.676	−4.340	−3.943	—	—	—	—
	(−1.00)	(−2.47)	(−2.24)				
Process only	—	—	—	−5.881	−5.898	−6.712	−6.816
				(−1.98)	(−1.99)	(−2.31)	(−2.37)
Process & product	—	—	—	−2.697	−2.658	−0.851	−0.861
				(−1.15)	(−1.14)	(−0.33)	(−0.33)
Sales growth – new pd	0.890 (12.61)	1.076 (11.17)	1.071 (12.55)	1.077 (10.66)	1.075 (10.77)	0.993 (11.62)	0.999 (11.79)
Industry dummies	—	—	—	Incl.	Incl.	Incl.	Incl.
Adj. R2	0.488	0.468	0.462	0.463	0.464	0.478	0.478
Root MSE	27.2	27.7	27.8	27.6	27.6	27.2	27.3
W_β (p-value)	—	0.375	0.407	0.447	0.452	0.936	0.994
PH_{all} (p-value)	—	—	—	—	—	0.950	—
PH_{lev} (p-value)	—	—	—	—	—	0.140	—
Hansen J	—	3.52	3.52	4.17	6.10	1.11	1.11
(df)		(2)	(2)	(2)	(2)	(4)	(4)
p-value		0.172	0.172	0.125	0.047	0.893	0.893

Notes: Number of firms: 1319. Large-sample z-statistics in brackets (standard errors robust to heteroskedasticity). Instruments: *R&D intensity, range* and *market novelty share* in (2)-(4), innovation intensity instead of R&D intensity in (5). *Continuous R&D, range, patent, client* and *science* in (6)-(7). Hansen J reports the test statistic of a test of overidentifying restrictions. Under the null hypothesis, J follows a $\chi^2(m)$ distribution with m as the number of overidentifying restrictions. The Wald test statistic W_β tests for the null hypothesis $\beta = 1$ and follows asymptotically a $\chi^2(1)$ distribution under the null hypothesis. Here, only the corresponding p-value is reported. Testing the orthogonality of *R&D intensity* in (4), we yield a C statistic of 4.158 (p-value: 0.041). For (6) the corresponding C statistics are: $C_{cont.R\&D} = 0.024$ (p-value: 0.877), $C_{range} = 0.729$ (0.393), $C_{patent} = 0.003$ (0.953), $C_{client} = 0.591$ (0.442), $C_{science} = 0.077$ (0.781).

rate. This impact tends to be larger in manufacturing than in services. Recall that β measures the relative efficiency across production processes, ie., if new products are produced more efficiently than the old ones, then this ratio is less than unity and employment does not grow one-for-one with the sales growth accounted for by new

Table 4: **Effects of Product and Process Innovations on Employment for Service Firms, 1998-2000.**

$$\text{Basic Model: } l - (g_1 - \widetilde{\pi}_1) = \alpha_0 + \alpha_1\, d + \beta\, g_2 + v$$

Dep. Variable	$l - g_1$		$l - (g_1 - \widetilde{\pi}_1)$				
Method	OLS	IV	IV	IV	IV	IV	GMM
Regression	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Expl. Variables	coeff. (t-stat)	coeff. (t-stat)	coeff. (t-stat)	coeff. (t-stat)	coeff. (t-stat)	coeff. (t-stat)	coeff. (t-stat)
Constant	−6.139 (−4.08)	−7.251 (−4.53)	−2.403 (−1.49)	−3.253 (−1.20)	−3.222 (−1.18)	−3.783 (−1.38)	−3.790 (−1.39)
Process	5.540 (2.33)	2.977 (1.24)	2.472 (1.03)	—	—	—	—
Process only	—	—	—	1.353 (0.46)	1.273 (0.43)	2.724 (0.91)	2.759 (0.93)
Process & product	—	—	—	3.041 (0.93)	3.283 (1.01)	−1.057 (−0.26)	−0.939 (−0.24)
Sales growth – new pd	0.765 (13.84)	0.882 (11.45)	0.851 (11.44)	0.833 (9.23)	0.825 (9.11)	0.965 (9.84)	0.962 (10.01)
Industry dummies	—	—	—	Incl.	Incl.	Incl.	Incl.
Adj. R2	0.420	0.411	0.395	0.416	0.417	0.391	0.392
Root MSE	33.7	33.9	34.1	33.4	33.4	34.1	34.1
W_β (p-value)	—	0.124	0.046	0.064	0.053	0.721	0.693
PH_{all} (p-value)	—	—	—	—	—	1.000	—
PH_{lev} (p-value)	—	—	—	—	—	0.714	—
Hansen J	—	8.20	7.95	9.84	10.21	0.11	0.11
(df)		(2)	(2)	(2)	(2)	(3)	(3)
p-value		0.017	0.019	0.007	0.006	0.990	0.990

Notes: Number of firms: 849. Large-sample z-statistics in brackets (standard errors robust to heteroskedasticity). Instruments: *R&D intensity, range* and *market novelty share* in (2)-(4), innovation intensity instead of R&D intensity in (5). *Continuous R&D, patent, client* and *science* in (6)-(7). Hansen J reports the test statistic of a test of overidentifying restrictions. Under the null hypothesis, J follows a $\chi^2\,(m)$ distribution with m as the number of overidentifying restrictions. The Wald test statistic W_β tests for the null hypothesis $\beta = 1$ and follows asymptotically a $\chi^2\,(1)$ distribution under the null hypothesis. Here, only the corresponding p-value is reported. Testing the orthogonality of each instrument in (6), we yield the following C statistics: $C_{cont.R\&D} = 0.098$ (p-value: 0.754), $C_{patent} = 0.002$ (0.962), $C_{client} = 0.035$ (0.852), $C_{science} = 0.006$ (0.938).

products. Jaumandreu (2003) found a unit elasticity of employment with respect to innovative output in terms of sales growth due to new products for Spanish firms. The t-tests show that the null hypothesis of a unit elasticity cannot be rejected for German firms in all estimations, even in the service sector.

Furthermore, the estimation results of the extended model, given in tables 5 and 6, suggest that new jobs are created not only in firms with market novelties, but also in those which successfully pursue imitation strategies. Both variables are significant and using an F-test, the null hypothesis that both coefficients are equal cannot be rejected. This result suggests that the employment effects do not vary significantly with the product novelty degree. This conclusion is valid for manufacturing as well as service firms. Hence, at least for the German manufacturing sector, this result is partly in contrast to previous conclusions drawn by Falk (1999).[20]

The constant can be interpreted as the average real productivity growth in the old process in the reference period that is not traceable to own process innovation activities (but, e.g., to organisational changes, improvements in human capital, learning or spill-over effects). The estimates show the expected negative sign and reasonable magnitudes for a two-years-period (about 2.7% p.a. in manufacturing and 1.9% in services). In any case, productivity advances in services seem to broadly differ from manufacturing for any firm (innovators and non–innovators). The constant is consistently lower, less significant and less robust.

In the theoretical model, the process innovation dummy should pick up additional efficiency gains and thus employment changes due to changes in the production process of the old product. However, the information in the data set does not allow to distinguish between process innovations applied to old or new products. To partially address this problem, we divide process innovators up into two groups: firms with process innovations only (corresponds by definition to old products) and firms with both product and process innovations, where changes in the production technology could be related to both old or new products.

The empirical analysis shows differences between the manufacturing and service sectors regarding the impact of process innovations: Process innovations were responsible for an employment reduction in the period 1998-2000 in the manufacturing, but not in the service sector. From a theoretical point of view, this can be interpreted in a way that displacement effects outweigh compensation effects in manufacturing, resulting in a negative employment effect. Conversely, the results suggest that service firms tend to react more aggressively, and passing on to prices just the productivity gains derived from innovations (or even more, as the coeffi-

[20] Using CIS 2 data covering the period 1994–1996 he showed that only market novelties have stimulated the expected labour demand. The expected employment change was an ordinal variable in the data set that implies a different estimation method (ordered probit model). Furthermore, he used dummy variables for both kinds of product innovations. Replacing the continuous variables in equation (11) with their dummy counterparts, however, did not alter the qualitative result.

Table 5: **Employment Effects of Different Types of Product and Process Innovations for Manufacturing Firms, 1998-2000.**

Extended Model: $l - g_1 - \widetilde{\pi}_1 = \alpha_0 + \alpha_c\, d_c + \alpha_{nc}\, d_{nc} + \beta_m\, g_{2m} + \beta_f\, g_{2f} + v$

Method	IV	IV	IV	IV	IV
Regression	(8)	(9)	(10)	(11)	(12)
Expl. Variables	coeff. (t-stat)	coeff. (t-stat)	coeff. (t-stat)	coeff. (t-stat)	coeff. (t-stat)
Constant	−5.790 (−3.67)	−5.891 (−3.72)	−5.829 (−3.66)	−9.620 (−3.84)	−9.291 (−3.43)
Process only	−6.652 (−2.30)	—	—	—	—
Process & product	−0.695 (−0.26)	—	—	—	—
Rationalisation	—	−3.075 (−1.58)	—	—	—
Other process	—	−2.459 (−0.76)	—	—	—
Rationalisation only	—	—	−8.102 (−2.35)	−7.758 (−2.27)	−7.443 (−2.23)
Other process only	—	—	−3.203 (−0.65)	−3.186 (−0.64)	−3.139 (−0.63)
Rational. & product	—	—	−0.362 (−0.16)	0.152 (0.07)	0.145 (0.06)
Sales growth – firm nov	1.053 (6.12)	1.052 (5.90)	1.042 (6.14)	0.988 (5.83)	0.989 (5.84)
Sales growth – market nov	0.891 (3.13)	0.992 (3.56)	0.891 (3.20)	1.014 (3.75)	1.024 (3.75)
SME	—	—	—	3.935 (1.81)	3.953 (1.82)
Investment	—	—	—	—	−7.909 (−0.41)
Industry dummies	Incl.	Incl.	Incl.	Incl.	Incl.
Adj. R2	0.477	0.472	0.478	0.477	0.476
Root MSE	27.3	27.4	27.2	27.2	27.3
$W_{\beta_f=\beta_m}$ (p-value)	0.700	0.889	0.718	0.950	0.932
Hansen J	1.01	1.32	0.97	1.08	1.22
(df)	(3)	(3)	(3)	(3)	(3)
p-value	0.798	0.726	0.808	0.781	0.749

Notes: Number of firms: 1319. Large-sample z-statistics in brackets (standard errors robust to heteroskedasticity). Instruments: Continuous intramural R&D activity, range, patent, client and science. The Wald test statistic $W_{\beta_f=\beta_m}$ tests for the null hypothesis $\beta_m = \beta_f$ and follows asymptotically a $\chi^2\,(1)$ distribution under the null hypothesis.

Table 6: **Employment Effects of Different Types of Product and Process Innovations for Service Firms, 1998-2000.**

Extended Model: $l - g_1 - \widetilde{\pi}_1 = \alpha_0 + \alpha_c\, d_c + \alpha_{nc}\, d_{nc} + \beta_m\, g_{2m} + \beta_f\, g_{2f} + v$

Method	IV	IV	IV	IV	IV
Regression	(8)	(9)	(10)	(11)	(12)
Expl. Variables	coeff. (t-stat)	coeff. (t-stat)	coeff. (t-stat)	coeff. (t-stat)	coeff. (t-stat)
Constant	−3.800	−3.688	−3.910	−3.383	−3.321
	(−1.35)	(−1.31)	(−1.42)	(−0.86)	(−0.85)
Process only	2.692	—	—	—	—
	(0.88)				
Process & product	−0.924	—	—	—	—
	(−0.14)				
Rationalisation	—	1.810	—	—	—
		(0.57)			
Other process	—	−1.596	—	—	—
		(−0.28)			
Rationalisation only	—	—	2.495	2.321	2.251
			(0.74)	(0.65)	(0.63)
Other process only	—	—	2.403	2.263	2.108
			(0.52)	(0.47)	(0.44)
Rational. & product	—	—	2.291	2.317	2.517
			(1.57)	(0.58)	(0.63)
Sales growth – firm nov	0.950	0.941	0.919	0.917	0.918
	(1.96)	(2.10)	(2.26)	(2.28)	(2.28)
Sales growth – market nov	0.978	0.952	0.960	0.953	0.957
	(2.30)	(2.12)	(2.13)	(2.23)	(2.23)
SME	—	—	—	−0.714	−0.692
				(−0.26)	(−0.26)
Investment	—	—	—	—	−3.413
					(−1.42)
Industry dummies	Incl.	Incl.	Incl.	Incl.	Incl.
Adj. R2	0.389	0.395	0.394	0.395	0.394
Root MSE	34.2	34.0	34.0	34.0	34.0
$W_{\beta_f=\beta_m}$ (p-value)	0.976	0.991	0.961	0.964	0.962
Hansen J	0.11	0.10	0.12	0.11	0.13
(df)	(2)	(2)	(2)	(2)	(2)
p-value	0.945	0.950	0.943	0.947	0.937

Notes: Number of firms: 849. Large-sample z-statistics in brackets (standard errors robust to heteroskedasticity). Instruments: Continuous intramural R&D activity, range, patent, client and science. The Wald test statistic $W_{\beta_f=\beta_m}$ tests for the null hypothesis $\beta_m = \beta_f$ and follows asymptotically a $\chi^2(1)$ distribution under the null hypothesis.

cient is positive but not significant). However, the results for services should be interpreted with more care as innovation processes in the service sector exhibit substantial differences compared to the manufacturing sector. In the service sector, the distinction between old and new services or processes is hindered by the fact that services are more often customized to specific demands, and that in many cases a clearly structured production process is lacking. Innovations in services are therefore more difficult to identify than in the manufacturing sector.

Moreover, the estimates show that only manufacturing firms which solely carried out process innovations experienced negative employment effects, while this was not the case for firms that introduced both new products and new processes. This result leads to the conclusion that different innovation strategies appear to be associated to different price behaviour. However, column 11 of table 5 further reveals that this is not true for all firms that exclusively introduced process innovations, but rather only for those firms which merely concentrated on rationalisation innovations. These varying effects of different types of process innovations may be one explanation as to why there is no clear empirical evidence of a robust (negative or positive) effect of process innovations on employment. The aims associated with the introduction of new production technologies (and thus, the composition of process innovations in the sample under consideration) may, for instance differ according to the level of economic activity or to different industries.[21]

Equation 10 was derived under the assumption of constant factor prices. Table 7 shows some further robustness checks of the basic model by relaxing this assumption and controlling for changes in average labour cost. The sample had to be reduced remarkably for this exercise because the *labour cost growth rate* could only be constructed by merging the German innovation surveys of 2001 and 1999 and the intersection of firms came to 55% in manufacturing and 30% in services.[22] The negative sign of the estimator associated with the labour cost variable is what we expected while the coefficients associated with the innovation variables are little affected. The coefficient of the sales growth due to new products has slightly declined in manufacturing and has decreased to a larger extent in services, however, this seemed to be the result of the reduced sample itself.

Note that industry dummies are included in all regressions. The estimation

[21] König et al. (1995) found a significant positive effect of process innovations for the boom period 1990-1992, while Blechinger and Pfeiffer (1999) reported a significant negative effect for the recession period 1993-1995.

[22] The core CIS questionnaire did not provide information on labour cost. The latter is an additional information in the German data set.

Table 7: **Effects of Innovations and Labour Costs on Employment, 1998-2000 (Reduced Sample).**

Basic Model: $l - (g_1 - \widetilde{\pi}_1) = \alpha_0 + \alpha_1\, d + \beta\, g_2 + v$

	Manufacturing			Services		
Expl. Variables	coeff. (t-stat)	coeff. (t-stat)	coeff. (t-stat)	coeff. (t-stat)	coeff. (t-stat)	coeff. (t-stat)
Constant	−5.461	−4.026	−3.883	−3.702	2.000	3.747
	(−2.98)	(−1.97)	(−1.90)	(−1.36)	(0.75)	(1.40)
Process only	−6.495	−5.894	−6.185	2.617	−6.995	−9.288
	(−2.27)	(−1.81)	(−1.93)	(0.88)	(−1.31)	(−1.96)
Process & product	−0.823	2.544	2.951	−1.045	3.632	3.100
	(−0.32)	(0.87)	(1.01)	(−0.26)	(0.50)	(0.44)
Sales growth – new pd	0.997	0.936	0.924	0.968	0.791	0.803
	(11.40)	(9.94)	(9.40)	(9.89)	(2.81)	(3.18)
Investment	−7.172	−13.315	−13.291	−3.208	4.270	1.370
	(−0.36)	(−0.72)	(−0.73)	(−1.36)	(0.48)	(0.19)
Labour cost growth	—	—	−0.093	—	—	−0.297
			(−2.07)			(−4.19)
Industry dummies	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.
Adj. R2	0.478	0.485	0.479	0.390	0.516	0.562
Root MSE	27.2	23.5	23.4	34.1	22.7	21.6
W_β (p-value)	0.970	0.494	0.414	0.746	0.456	0.435
Hansen J	1.18	1.01	1.02	0.13	2.71	2.87
(df)	(4)	(4)	(4)	(3)	(3)	(3)
p-value	0.882	0.908	0.907	0.987	0.439	0.412
No. of firms	1319	701	701	849	257	257

Notes: Large-sample z-statistics in brackets (standard errors robust to heteroskedasticity). Instruments: Continuous intramural R&D activity, range (only in manufacturing), patent, client and science.

equation is specified in growth rates, i.e., in first differences. This implies that time-invariant firm-specific (observable and unobservable) effects in the employment levels are eliminated. However, the inclusion of industry dummies enlarge the flexibility of the specification by allowing for an unspecified form of heterogeneity in the growth rates between industries. Similarily, firm size (proxied by two different size classes according to employment) was partly included, but was only found to be weakly significant in manufacturing.

7 Conclusion

Using the approach recently proposed by Jaumandreu (2003), I have analysed the relationship between the employment growth rate and innovation output in terms of sales growth generated by new products and process innovations at the firm level. As employment effects are expected to differ according to the type of innovation, I extended the analysis by distinguishing between (i) two different product innovation outputs according to the novelty degree (sales growth generated by market novelties and those generated by firm novelties) and (ii) two different process innovation indicators (rationalisation and other process innovations, respectively).

The econometric results confirm that successful product innovations have a positive impact on net employment at the level of the innovating firm. The impact tends to be larger in manufacturing than in service firms, although the difference is statistically not significant. The results further provide evidence that the employment does grow one-for-one with the sales growth accounted for by new products. In addition to that, the estimation results indicate that new jobs are not only created in firms launching market novelties, but also in firms which successfully pursue product imitation strategies. Moreover, the coefficients of both indicators of product innovation success were not significantly different. This holds for manufacturing and service firms. Hence, this result contradicts the hypothesis that employment effects depend on the degree of product novelty.

The impact of process innovations on employment growth turns out to be variable. In manufacturing firms, displacement effects outweigh compensation effects, resulting in a negative employment effect. But, as expected, the estimation results also reveal that not all process innovations are associated with employment reduction. Jobs are merely significantly deteriorated through rationalisation innovations, but not as a consequence of other process innovations. In contrast, process innovations are not responsible for a significant reduction in labour demand in service firms in the period 1998-2000.

Finally, from an international perspective the results for the employment effects of product innovations are very similar to those found for Spain, UK and France, thus supporting a discernible international pattern in the firm-level association between innovation and employment. However, the empirical analysis reveals different impacts of process innovations.

The potential employment effects of innovations may even be underestimated for the boom period 1998-2000 because a growing number of firms reported for that period that they could not meet their demand for qualified personnel (see Ebling et al. 2000).

These empirical findings on employment effects are restricted to the level of the innovating firm, while neglecting the wider consequences. On a sector or aggregate level, technological change may be associated with further impacts on firms' labour demand, which are beyond the scope of the present study.

The model developed by Jaumandreu (2003) could serve as a promising starting point for further research. This may include the modelling of a firm's decision to innovate or not or the modelling of employment effects differentiated by labour skills.

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Data Appendix

The data set used is based on the 2001 official innovation survey in the German manufacturing and service industries, which was the German part of the Community Innovation Surveys CIS 3. In Germany, the survey was conducted by the Centre for European Economic Research (ZEW) on behalf of the German government. The survey covers legally independent German firms from the sectors mining and quarrying, manufacturing, electricity, gas and water supply as well as construction (NACE classes 10-14, 15-37, 40-41 and 45) and from various service sectors (NACE 50-52, 60-64, 65-67, 70-74, 90). The sample of the innovation survey is drawn as a stratified random sample. Firm size (8 size classes according to the number of employees), sector (according to two-digit NACE classes) and region (East and West Germany) serve as stratifying variables. The innovation survey is performed voluntarily by mail. For a detailed description of the survey methodology as well as the surveyed information, see Janz et al. (2001).

Table 8: **Sample by Industries.**

	Nace	Total		Non-innovator		Process only		Product only		Product & process	
		#	%	#	%	#	%	#	%	#	%
Manufact.											
Food	15 – 16	113	*8.6*	72	*63.7*	7	*6.2*	13	*11.5*	21	*18.6*
Textile	17 – 19	77	*5.8*	48	*62.3*	7	*9.1*	16	*20.8*	6	*7.8*
Wood/print.	20 – 22	112	*8.5*	58	*51.8*	21	*18.8*	11	*9.8*	22	*19.6*
Chemicals	23 – 24	92	*7.0*	28	*30.4*	10	*10.9*	21	*22.8*	33	*35.9*
Plastic/rubber	25	116	*8.8*	39	*33.6*	10	*8.6*	28	*24.1*	39	*33.6*
Glass/ceram.	26	78	*5.9*	39	*50.0*	4	*5.1*	14	*18.0*	21	*26.9*
Metals	27 – 28	227	*17.2*	113	*49.8*	40	*17.6*	23	*10.1*	51	*22.5*
Machinery	29	184	*14.0*	58	*31.5*	14	*7.6*	55	*29.9*	57	*31.0*
Elec. engin.	30 – 33	214	*16.2*	46	*21.5*	9	*4.2*	75	*35.1*	84	*39.3*
Vehicles	34 – 35	53	*4.0*	21	*39.6*	4	*7.6*	11	*20.8*	17	*32.1*
Furniture/rec.	36 – 37	53	*4.0*	25	*47.2*	8	*15.1*	10	*18.9*	10	*18.9*
Total		**1319**	***100***	**547**	***41.5***	**134**	***10.2***	**277**	***21.0***	**361**	***27.4***
Services											
Wholesale	51	204	*24.0*	131	*64.2*	16	*7.8*	28	*13.7*	29	*14.2*
Transport	60 – 63	204	*24.0*	143	*70.1*	20	*9.8*	18	*8.8*	23	*11.3*
Post/telec.	64	26	*3.1*	19	*73.1*	1	*3.9*	2	*7.7*	4	*15.4*
Financial int.	65 – 67	97	*11.4*	36	*37.1*	10	*10.3*	12	*12.4*	39	*40.2*
Computer	72	80	*9.4*	16	*20.0*	4	*5.0*	33	*41.3*	27	*33.8*
Res. & dev.	73	75	*8.8*	15	*20.0*	8	*10.7*	20	*26.7*	32	*42.7*
Techn. serv.	742 – 743	163	*19.2*	76	*46.6*	20	*12.3*	37	*22.7*	30	*18.4*
Total		**849**	***100***	**436**	***51.4***	**79**	***9.3***	**150**	***17.7***	**184**	***21.7***

Notes: Entrants and firms affected by merger, sale or closure are excluded, as are firms with less than 10 employees in 2000 or those lacking complete information.

Table 9: **Sample by Size Classes.**

Employees	Total		Non-innovators		Process only		Product only		Product & process	
	#	%	#	%	#	%	#	%	#	%
Manufacturing										
10 – 19	193	*14.6*	115	*59.6*	18	*9.3*	35	*18.1*	25	*13.0*
20 – 49	321	*24.3*	177	*55.1*	30	*9.4*	63	*19.6*	51	*15.9*
50 – 99	244	*18.5*	109	*44.7*	23	*9.4*	53	*21.7*	59	*24.2*
100 – 199	198	*15.0*	74	*37.7*	25	*12.6*	44	*22.2*	55	*27.8*
200 – 499	221	*16.8*	47	*21.3*	25	*11.3*	54	*24.4*	95	*43.0*
500 – 1000	91	*6.9*	17	*18.7*	10	*11.0*	18	*19.8*	46	*50.6*
> 1000	51	*3.9*	8	*15.7*	3	*5.9*	10	*19.6*	30	*58.8*
Total	**1319**	***100***	**547**	***41.5***	**134**	***10.2***	**277**	***21.0***	**361**	***27.4***
Services										
10 – 19	266	*31.3*	159	*59.8*	21	*7.9*	48	*18.1*	38	*14.3*
20 – 49	257	*30.3*	153	*59.5*	20	*7.9*	46	*17.9*	38	*14.8*
50 – 99	127	*15.0*	59	*46.5*	18	*14.2*	21	*16.5*	29	*22.8*
100 – 199	87	*10.3*	35	*40.2*	7	*8.1*	15	*17.2*	30	*34.5*
200 – 499	46	*5.4*	18	*39.1*	5	*10.9*	8	*17.4*	15	*32.6*
500 – 1000	33	*3.9*	7	*21.2*	5	*15.2*	8	*24.2*	13	*39.4*
> 1000	33	*3.9*	5	*15.2*	3	*9.1*	4	*12.1*	21	*63.4*
Total	**849**	***100***	**436**	***51.4***	**79**	***9.3***	**150**	***17.7***	**184**	***21.7***

Notes: Entrants and firms affected by merger, sale or closure are excluded, as are firms with less than 10 employees in 2000 or those lacking complete information.

Table 10: **First Step Estimation Results.**

Regression	(6)		(10)			
Endogenous Var.	sales growth – new pd		sales growth – firm nov		sales growth – market nov	
Sample	Manuf.	Services	Manuf.	Services	Manuf.	Services
Exog. Variables	coeff. (t-stat)	coeff. (t-stat)	coeff. (t-stat)	coeff. (t-stat)	coeff. (t-stat)	coeff. (t-stat)
Constant	−0.420 (−0.17)	0.600 (0.27)	−.226 (−0.13)	0.640 (0.39)	0.338 (0.19)	1.183 (0.76)
Process only	−15.191 (−6.22)	−12.507 (−3.38)	—	—	—	—
Process & product	9.509 (4.95)	21.936 (7.67)	—	—	—	—
Rationalisation only	—	—	−10.815 (−5.56)	−10.695 (−2.89)	−5.856 (−2.86)	−6.286 (−1.82)
Other process only	—	—	−11.664 (−4.04)	−10.023 (−2.64)	−5.799 (−1.91)	−5.834 (−1.65)
Rational. & product	—	—	4.611 (3.31)	6.894 (2.66)	0.672 (0.46)	7.180 (2.97)
Cont. R&D	8.687 (4.41)	11.662 (3.79)	3.086 (2.28)	8.470 (3.72)	6.709 (4.70)	5.291 (2.49)
Range	9.490 (4.81)	—	9.019 (6.64)	—	1.794 (1.25)	—
Client	7.079 (3.68)	6.354 (2.42)	5.227 (3.92)	4.625 (2.39)	2.226 (1.58)	3.928 (2.17)
Science	7.372 (2.67)	12.706 (2.66)	6.343 (3.31)	12.506 (3.53)	1.426 (0.71)	1.340 (0.40)
Patent	0.813 (0.43)	17.960 (4.14)	−2.195 (−1.69)	3.880 (1.21)	3.596 (2.62)	15.432 (5.13)
Industry dummies	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.
Adj. R2	0.28	0.31	0.23	0.19	0.10	0.14
Partial R2	0.116	0.096	0.128	0.070	0.061	0.073
F	34.13	22.08	38.12	15.63	16.91	16.50
(p-value)	0.000	0.000	0.000	0.000	0.000	0.000

Notes: The F statistic tests for the null hypothesis that the excluded instruments (*Continuous R&D, patent, client, science* and, in manufacturing, *range*) are jointly zero. Partial R2 reports the partial R-squared of excluded instruments.

Table 11: **Quantitative Variables.**

Variable	Definition
Employment growth	Rate of change of the firm's overall employment for period 1998-2000.
Sales growth	Rate of change of the firm's turnover for the period 1998-2000.
Sales growth – new pd	Rate of change of the firm's turnover due to product innovations for the period 1998-2000. Computed as: [*share of sales in 2000 due to new products introduced between 1998-2000 * (sales in 2000/sales in 1998)*].
Sales growth – market nov	Rate of change of the firm's turnover due to market novelties for the period 1998-2000.
Sales growth – firm nov	Rate of change of the firm's turnover due to firm novelties for the period 1998-2000.
Sales growth – old pd	Rate of change of the firm's turnover due to unchanged products for the period 1998-2000. Computed as: [*sales growth - sales growth due to new products*].
Price growth	Price growth for the period 1998-2000.
Labour cost growth	Rate of change of the firm's average labour costs (total remuneration plus social contributions) per employee during 1998-2000.
Investment	Sum of investments in tangible assets in 1998, 1999 and 2000 per employee in 1998.
R&D intensity	Ratio of total R&D expenditure to sales in 2000.
Innovation intensity	Ratio of total innovation expenditure to turnover in 2000.
Market novelties share	Share of turnover in 2000 due to new or significantly improved products introduced during 1998-2000 which are new for the firms market.
Export intensity	Ratio of exports to sales in 2000.
Export growth	Growth rate of firm's exports (x) between 1998-2000. To avoid the effect of zeroes for non-exports in the base year, it was computed as $[2(x_{2000} - x_{1998})/(x_{2000} + x_{1998})]$.

Table 12: **Qualitative Variables.**

Variable	Definition
Product	Introduction of at least one new or significantly improved product during 1998-2000.
Firm novelty	Introduction of at least one new or significantly improved product during 1998-2000 which was new for the firm but not for the market.
Market novelty	Introduction of at least one new or significantly improved product during 1998-2000 which was new to the firm's market.
Process	Introduction of new or significantly improved production technologies or methods of supplying and delivering products or procedures during 1998-2000.
Rationalisation	Introduction of at least one process innovation intended for rationalisation purposes in terms of reducing production costs in 1998-2000.
Product only	Dummy variable being 1 if Product=1 and Process=0
Process only	Dummy variable being 1 if Product=0 and Process=1
Product & Process	Dummy variable being 1 if Product=1 and Process=1
Other Process	Dummy variable being 1 if Process=1 and Rationalisation=0
Rationalisation only	Dummy variable being 1 if Process=1 and Rationalisation=1 and Product=0
Other Process only	Dummy variable being 1 if Process=1 and Rationalisation=0 and Product=0
Rational. & Product	Dummy variable being 1 if Process=1 and Rationalisation=1 and Product=1
Continuous R&D	Firm was engaged continuously in intramural R&D activities during 1998-2000.
Market	Effect of innovation has had a high to medium-sized impact on increased market or market share.
Range	Effect of innovation has had a high to medium-sized impact on an increased range of goods and services.
Quality	Effect of innovation has had a high to medium-sized impact on improved quality in goods or services.
Client	Clients have been a large to medium-sized source of innovation.
Science	Science (universities, public research institutes) has been a high to medium-sized source of innovation.
Patent	Firm applied for a patent during 1988-2000.
SME	Firms with less than 500 (manufacturing) and 100 (services) employees, respectively.
Industry dummies	System of 11 and 7 dummies grouping industries and services, respectively (see table 8).