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## Innovations, prices, and employment: A theoretical model and an empirical application for West-German manufacturing firms

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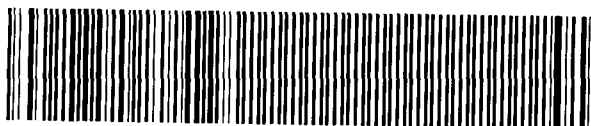
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Werner Smolny

Innovations, Prices, and Employment  
A Theoretical Model and an Empirical  
Application for West-German  
Manufacturing Firms

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# Innovations, Prices, and Employment

A Theoretical Model and an Empirical Application  
for West-German Manufacturing Firms

Werner Smolny

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# Innovations, Prices, and Employment

## A Theoretical Model and an Empirical Application for West-German Manufacturing Firms

Werner Smolny

Universität Konstanz

October 1996

### Abstract:

In this paper, a theoretical model of the impact of product and process innovations on output, capacity utilization, employment, and prices is developed. The model is estimated with micro-data for West German manufacturing firms from the ifo firm panel. The empirical results reveal that innovative firms exhibit a higher utilization and more output and employment growth than non-innovative firms. Innovations also change the market structure. The frequency of price and output changes is lower and the frequency of employment changes is higher in sectors with a large share of product innovators, and vice versa in sectors with a large share of process innovators.

Keywords: Innovations, price setting, market structure

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# 1 Introduction

Innovations increase the quality of goods and reduce the input requirement. Therefore, innovative firms should be more competitive and increase output and employment. On the other hand, innovations increase product differentiation and thereby tend to reduce competition. This can lead to higher prices and less output and employment. In the paper, a theoretical model of the impact of innovative activities on output, prices, and employment is developed and estimated with micro-data for West German manufacturing firms.

The basic premise of most endogenous growth models is that technological progress is driven by "... an intentional investment of resources by profit-seeking firms or entrepreneurs."<sup>1</sup> Firms invest in R&D and introduce innovations in order to reduce costs or to increase demand. Since the knowledge incorporated in innovations is non-rival and only partially excludable, the firm size and the market structure are important determinants of innovations:<sup>2</sup> large firms on monopolistic markets must fear less imitation from competitors and gain more from scale economies associated with innovations. In addition, monopolistic profits permit an easier finance of risky innovation projects.<sup>3</sup> On the other hand, small firms on competitive markets are forced to utilize the best available production technique and to develop better products. Non-innovative firms must fear to be driven out of the market, while firms which successfully introduce an innovation gain from a large increase of the market share.

However, the market structure itself is endogenous.<sup>4</sup> Innovations of firms change the market structure, and the intended change of the market structure can be an important incentive for innovative activities: firms develop differentiated products to become less dependent on the market behaviour of competitors. If they are successful, i.e. if the price elasticity of demand is reduced, product innovations can result in higher prices and less output and employment. In addition, demand reacts less with respect to changes of competitors' behaviour. Demand uncertainty is lower, and the firm must change output and prices less often. On the other hand, a high intensity of process innovations on the market is probably associated with stronger price competition and more demand variance.

The contribution of the paper is the theoretical and empirical analysis of the effects of innovations on the price, output, and employment adjustment of the firm. The idea is to receive some information about the impact of innovations on the market structure from analyzing the impact of innovations on the price, output, and employment adjustment of the firm. It is assumed that product innovations change the demand curve and process innovations

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<sup>1</sup>Grossman, Helpman (1994), p. 24. See also Romer (1990), Grossman, Helpman (1991), Aghion, Howitt (1992), and Ramser (1992).

<sup>2</sup>See Kamien, Schwarz (1975,1982), Acs, Audretsch (1987,1988), Cohen, Levin (1989), and Scherer, Ross (1990).

<sup>3</sup>See Greenwald, Kohn, Stiglitz (1990), Stiglitz (1993), Ramser (1996), and Winker (1996).

<sup>4</sup>See Dixit, Stiglitz (1977), Dasgupta, Stiglitz (1980a,1980b), and Pohlmeier (1992).

change costs through the productivities of labour and/or capital. The behaviour of other firms is treated as exogenous or predetermined,<sup>5</sup> but it is allowed for spillovers from their innovation activities. The possibility to imitate others' new products increases the productivity of own product innovations, and technology spillovers increase the productivity of own process innovations and investment.<sup>6</sup> On the other hand, the increased competition from other firms with better products and lower costs tends to reduce demand and therefore output, prices, and labour demand.

In the model, a delayed adjustment of prices and employment with respect to demand shocks is assumed to allow for short-run demand induced changes.<sup>7</sup> In the short run, only output is treated as endogenous. In the medium run, the firms adjust employment and prices with respect to demand shocks. Innovations and investment are determined in the long run and are treated as predetermined for the price and employment decision. The market structure is also treated as predetermined. In this paper, only the short- and medium-run model is discussed in detail, the analysis of the determinants of investment and innovations is discussed in a subsequent paper.<sup>8</sup>

The empirical analysis is carried out with firm level data for West German manufacturing from the *ifo firm panel*. The data set contains informations for 2405 firms for the period from 1980 to 1992 from the business survey, the innovation survey, and the investment survey of the ifo institute.<sup>9</sup> From the business survey, qualitative monthly data on price and output changes and quarterly data on employment changes and capacity utilization are available. Since 1980, the business survey also contains an annual question on innovations.<sup>10</sup> The data-set contains the qualitative information, whether a firm has implemented product and/or process innovations. These data were matched with quantitative annual data on investment, employment, and sales from the investment survey. The time-series dimension of the data set allows to estimate the effects of innovations on the adjustment processes of output, prices, and employment. In the empirical model, price and employment changes are explained with short-run demand shocks, own product and process innovations and investment, and others' product and process innovations. In addition, the high frequency of the data permits the analysis of the effects of innovations on the volatility of output, prices, and employment.

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<sup>5</sup>That means, it is abstracted from strategic interaction among firms.

<sup>6</sup>See Jaffee (1986), Levin, Reiss (1988), Young (1993), Nadiri (1993).

<sup>7</sup>The assumption of a delayed adjustment is common for investment models. See e.g. Kydland, Prescott (1982) and Smolny (1993). A delayed adjustment of prices is analyzed by Maccini (1981), Sneessens (1987), de la Croix (1992), Smolny (1994), and Andersen (1996).

<sup>8</sup>See Smolny (1996). In addition, the paper is confined to partial analysis. Katsoulacos (1984) analyzes the employment effects of process innovations in a general equilibrium model.

<sup>9</sup>See Schneeweis, Smolny (1996) and Smolny, Schneeweis (1996).

<sup>10</sup>See Oppenländer, Poser (1989) and Penzkofer, Schmalholz, Scholz (1989).



## 2 Theoretical framework

### 2.1 The model of the firm

#### 2.1.1 Assumptions

In the theoretical model, a strong separability of the short-run, the medium-run, and the long-run decisions is assumed. In the short run, only output is endogenous. Output is adjusted with respect to demand shocks. Since prices, employment, and capacities are predetermined, an insufficient supply can restrain output. On the other hand, negative demand shocks lead to an underutilization of labour and capital.<sup>11</sup> In the medium run, the firm decides on prices and employment under uncertainty of demand. The price and employment decision is affected by wage costs, predetermined capacities, and the expectation about the development of demand. Wages are treated as exogenous. In the long run, the firm decides on innovations, investment, and capital-labour substitution under uncertainty about demand, employment and prices. Process innovations and capital investment determine capacities and the capital-labour ratio, and product innovations affect the demand curve. It is distinguished between effects on the level of demand, on the price elasticity of demand, and on the variance of demand shocks. It is also allowed for effects of other firms' innovations on the demand curve and production costs, i.e. effects from their innovations on demand, the market structure, and the factor productivities are taken into account.

In most models, a dynamic adjustment is analyzed under the assumption that adjustment costs depend on the size of the adjustment. However, it is difficult to find examples for adjustment costs which can account for the observed slow adjustment of many economic variables, especially of prices. On the other hand, changing decision variables necessarily takes time, and even a short time delay between a decision and the realization of an exogenous variable can introduce considerable uncertainty.<sup>12</sup> The analysis of the dynamic adjustment in terms of adjustment delays and uncertainty has the further advantage to reduce the dynamic decision problem of the firm to a sequence of static problems which can be solved stepwise.<sup>13</sup>

- output determination can be analyzed with predetermined prices, employment, capacities, and "knowledge capital";
- the medium-run decision on prices and employment can be analyzed under uncertainty of demand, taking into account the short-run decision on output;

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<sup>11</sup>In order to preserve analytical tractability, a short-run adjustment of the working time and finished goods inventory adjustments are neglected.

<sup>12</sup>See Maccini (1981), Sneesens (1987), de la Croix (1992), and Smolny (1994).

<sup>13</sup>A corresponding sequential adjustment can be found in the literature on wage bargaining ("right-to-manage" models). See e.g. de la Croix (1992).

- the long-run decision on innovations and investment can be analyzed under uncertainty of demand, employment, and prices, taking into account the structure of the short- and medium-run decision problems.

The analysis is carried out within a framework of monopolistic competition. In order to distinguish between demand shifts, the price elasticity of demand, and demand uncertainty, a log-linear demand curve is assumed.<sup>14</sup>

$$\ln YD = \eta \cdot \ln p + \ln Z + \varepsilon \quad (1)$$

with:  $\eta < -1$ ,  $E(\varepsilon) = 0$ ,  $\text{Var}(\varepsilon) = \sigma^2$

Demand  $YD$  depends negatively on the price  $p$  with a constant elasticity  $\eta$ , exogenous or predetermined factors incorporated in  $Z$ , and an error term  $\varepsilon$  which is not known at the time of the price and employment decision. The time index is omitted for convenience.  $Z$ ,  $\eta$ , and  $\sigma$  are treated as predetermined in the short run, but depend on own and others' innovations in the long run. Supply  $YS$  is determined by a short-run limitational production function with capital  $K$  and labour  $L$  as inputs:

$$YS = \min(YC, YL) = \min(\pi_k \cdot K, \pi_l \cdot L) \quad (2)$$

$YC$  are capacities,  $YL$  is the employment constraint, and  $\pi_l$ ,  $\pi_k$  are the productivities of labour and capital. Both productivities are treated as predetermined in the short run, but depend on relative factor prices and (own and others') process innovations in the long run.

### 2.1.2 An immediate adjustment of prices and employment

As a starting point, the results from the simple model with an immediate adjustment of output, prices, and employment are discussed. This is a special case of the general model for the absence of uncertainty about demand at the time of the price and output decision (i.e.  $E(\varepsilon) = \varepsilon$ ,  $\sigma = 0$ ). The model then consists of a two-step decision structure; capacities and innovations are determined in the long run. The optimization problem can be written as:

$$\max_{\rightarrow L} p \cdot Y - w \cdot L - c \cdot K \quad \text{s.t.} \quad Y \leq \{YC, YL, YD\} \quad (3)$$

$w$  are wages and  $c$  captures the user costs of all kinds of capital, i.e. physical capital and "knowledge capital". The first order condition is:

$$\begin{aligned} p \cdot \frac{\partial Y}{\partial YL} \cdot \frac{\partial YL}{\partial L} + \frac{\partial p}{\partial Y} \cdot \frac{\partial Y}{\partial YL} \cdot \frac{\partial YL}{\partial L} \cdot Y - w &= \\ p \cdot (1 + 1/\eta) \cdot (1 - \lambda_{YC}) \cdot \pi_l - w &= 0 \end{aligned} \quad (4)$$

<sup>14</sup>See Barro (1972), Dixit, Stiglitz (1977) and Blanchard, Kiyotaki (1987). Deaton, Muellbauer (1980) derive logarithmic demand curves from CES-utility functions.

$\lambda_{YC}$  is the shadow price of the capacity constraint; it is zero in case of sufficient capacities and one in case of capacity shortages:

$$\lambda_{YC} = \begin{cases} 0 & \text{for } \varepsilon < \bar{\varepsilon} \\ 1 & \text{for } \varepsilon > \bar{\varepsilon} \end{cases}$$

$\bar{\varepsilon}$  is defined by:  $\bar{\varepsilon} := \ln YC - \eta \cdot \ln p(w) - \ln Z$

For the optimal solution, two cases can be distinguished: in case of sufficient capacities (i.e.  $\lambda_{YC} = 0$ ), the optimal price, output, and employment result from:

$$p(w) = \frac{w}{\pi_l \cdot (1 + 1/\eta)} \quad (5)$$

$$\ln Y(w) = \eta \cdot \ln p(w) + \ln Z + \varepsilon \quad (6)$$

$$\ln L(w) = \ln Y(w) - \ln \pi_l \quad (7)$$

The price is determined by unit labour costs and the price elasticity of demand, output results from introducing this price into the demand function, and employment is the labour input required to produce this output. In case of capacity shortages (i.e.  $\lambda_{YC} \neq 0$ ), output, employment, and prices result from:

$$Y = YC \quad (8)$$

$$\ln L_{YC} = \ln YC - \ln \pi_l \quad (9)$$

$$\ln p(YC) = (\ln YC - \ln Z - \varepsilon)/\eta \quad (10)$$

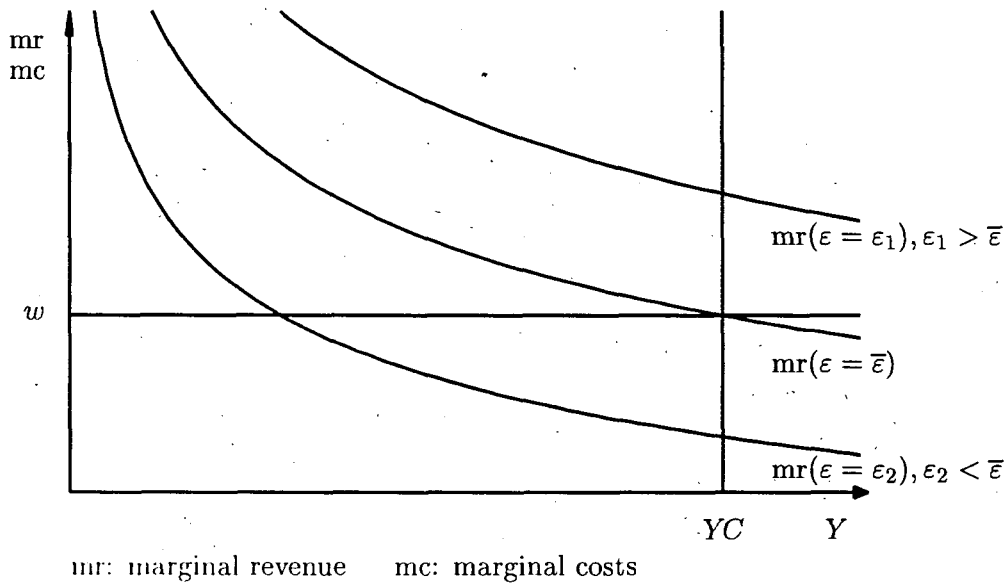
Output is equal to the capacity constraint, employment is again given as the corresponding labour requirement, and the price results from solving the demand function for  $p$  at  $YD = YC$ . There is exactly one value of the demand shock  $\varepsilon = \bar{\varepsilon}$  which distinguishes these cases. Figure 1 gives a visual impression of the model. In case of a negative demand shock ( $\varepsilon_2 < \bar{\varepsilon}$ ), the price is determined by unit labour costs and the mark-up is determined by the price elasticity of demand. The firm suffers from underutilization of capacities. In case of a positive demand shock ( $\varepsilon_1 > \bar{\varepsilon}$ ), insufficient capacities restrain output and the firm increases the price.  $\varepsilon = \bar{\varepsilon}$  is the borderline which distinguishes these cases. That means, in the short run the firm adjusts with respect to demand

- either by changing the price (in the capacity constrained regime),
- or by changing output and employment (in the unconstrained regime).

Solving the model for the long run yields optimal capacities and the optimal productivity of labour which determine the optimal value of  $\bar{\varepsilon}$ .<sup>15</sup> Both are

<sup>15</sup>See Smolny (1996).

Figure 1: Optimal output



mainly determined by the relation of labour and capital costs  $w/c$ , but depend also on the price elasticity of demand and the variance of demand shocks.  $\bar{\epsilon}$ , in turn, determines the short-run regime probabilities and the average utilization of capital. In addition,  $Z$ ,  $\sigma$  and  $\eta$  are treated as endogenous, i.e. depend on product innovations.

### 2.1.3 A delayed adjustment of prices and employment

Now consider the case that prices and employment are set with a delay and thus under uncertainty of demand. Adjustment delays for employment can be easily justified with adjustment costs, legal/contractual periods of notice, and searching time.<sup>16</sup> The assumption that the firm sets price tags also appears reasonable,<sup>17</sup> and even a short time delay between the price decision and the realization of demand can introduce considerable uncertainty. Investment and innovations are determined in the long run, therefore those variables can be treated as predetermined for the price and employment decision. In the short run, output  $Y$  is given by the minimum of demand and supply:

$$Y = \min(YD, YS) \quad (11)$$

<sup>16</sup>See Blanchard, Diamond (1992), Smolny (1993), and Hamermesh, Pfann (1996).

<sup>17</sup>See Arrow (1959), Sheshinski, Weiss (1977), Maccini (1981), Precious (1985), Carlton (1989), Benassy (1993), and Smolny (1994).

Supply is given by the minimum of the capacity constraint and the employment constraint of the short-run limitational production function. Demand depends on the predetermined price and the realization of the demand shock  $\varepsilon$ . Expected output is given by:<sup>18</sup>

$$E(Y) = E[\min(YD, YS)] = \int_{-\infty}^{\bar{\varepsilon}} YD \cdot f_{\varepsilon} d\varepsilon + \int_{\bar{\varepsilon}}^{\infty} YS \cdot f_{\varepsilon} d\varepsilon \quad (12)$$

with:  $\bar{\varepsilon} := \ln YS - \eta \cdot \ln p - \ln Z$

$YD$  is the demand function, eq. (1), and supply  $YS$  is determined by the short-run limitational production function, eq. (2) above.  $f_{\varepsilon}$  is the probability distribution function (p.d.f.) of the demand shock  $\varepsilon$ . For low values of  $\varepsilon$ , output is determined by demand (the first integral); for high values of  $\varepsilon$ , output is determined by supply (the second integral); there is one value of the demand shock  $\varepsilon = \bar{\varepsilon}$  which distinguishes these cases.  $\bar{\varepsilon}$  defines the situation that supply equals demand.  $E(Y)$  depends on employment, the price, and the parameters of the production function and the demand function. The medium-run optimization problem is:

$$\max_{\rightarrow L, p} p \cdot E(Y) - w \cdot L - c \cdot K \quad (13)$$

Note that the firm must set prices and decide on employment before it knows the location of the demand curve, i.e. there is uncertainty about the demand shock  $\varepsilon$ . The first order conditions of the optimization problem with respect to prices and employment are given by:

$$p \cdot \frac{\partial E(Y)}{\partial p} + E(Y) = 0 \quad (14)$$

$$p \cdot \frac{\partial E(Y)}{\partial YS} \cdot \frac{\partial YS}{\partial YL} \cdot \frac{\partial YL}{\partial L} - w = 0 \quad (15)$$

Partial differentiation of expected output with respect to the price yields:<sup>19</sup>

$$\frac{\partial E(Y)}{\partial p} = \eta \cdot \int_{-\infty}^{\bar{\varepsilon}} \frac{YD}{p} \cdot f_{\varepsilon} d\varepsilon \quad (16)$$

Inserting eqs. (12) and (16) into the first order condition for prices, eq. (14), yields

$$(1 + \eta) \cdot \int_{-\infty}^{\bar{\varepsilon}} YD \cdot f_{\varepsilon} d\varepsilon + \int_{\bar{\varepsilon}}^{\infty} YS \cdot f_{\varepsilon} d\varepsilon = 0 \quad (17)$$

which can be reformulated as:

$$(1 + \eta) \cdot \int_{-\infty}^{\bar{\varepsilon}} \exp(\varepsilon - \bar{\varepsilon}) \cdot f_{\varepsilon} d\varepsilon + \int_{\bar{\varepsilon}}^{\infty} f_{\varepsilon} d\varepsilon = 0 \quad (18)$$

<sup>18</sup>This expression refers to  $E_{t-\tau}(Y_t)$ , i.e. expected output for  $t$ , expected at  $t - \tau$ .

<sup>19</sup>Note that the value of both integrands in (12) at  $\varepsilon = \bar{\varepsilon}$  is equal.

This implies that the optimal value of  $\bar{\varepsilon}$  depends only on  $\eta$  and on the parameters of the p.d.f. of  $\varepsilon$ . Assuming a p.d.f. of  $\varepsilon$  which is completely characterized by its expected value and its variance  $\sigma^2$ , it can be written as:

$$\bar{\varepsilon} = h(\eta, \sigma) \quad (19)$$

The price is determined as:<sup>20</sup>

$$\ln p = \left[ \ln YS - \ln Z - h(\eta, \sigma) \right] / \eta \quad (20)$$

The price depends through a loglinear function on the demand shift parameter  $Z$ , supply  $YS$ , and a third term determined by the degree of uncertainty about demand and the price elasticity of demand. The absolute value of the elasticity of the price with respect to supply and the demand shift is equal to  $1/\eta$ . The following properties can be derived. The probability that demand is less than supply is given by:

$$\text{prob}(YD < YS) = \int_{-\infty}^{\bar{\varepsilon}} f_{\varepsilon} d\varepsilon \quad (21)$$

This probability depends only on  $\sigma$  and  $\eta$  and is independent of supply and the demand shift parameter  $Z$ ! Note that this result holds irrespective of capacity constraints. From eqs. (12) and (17), one can determine the *weighted* probability of the demand constrained regime, i.e. the expected share of output in the demand constrained regime. It is chosen equal to the inverse of the absolute value of the price elasticity of demand and is therefore also independent of supply and the demand shift:

$$\text{prob}_w(YD < YS) := \frac{\int_{-\infty}^{\bar{\varepsilon}} YD \cdot f_{\varepsilon} d\varepsilon}{\int_{-\infty}^{\bar{\varepsilon}} YD \cdot f_{\varepsilon} d\varepsilon + \int_{\bar{\varepsilon}}^{\infty} YS \cdot f_{\varepsilon} d\varepsilon} = -\frac{1}{\eta} \quad (22)$$

The economic intuition behind this result is that (for given supply and costs) the elasticity of output with respect to the price is chosen equal to one: in case of a price increase, demand decreases with elasticity  $\eta$ ; expected output decreases with elasticity  $\eta$ , *times the weighted probability that demand is less than supply*. One can also determine the expected utilization of supply. From eq. (12), (17), and (21) one can derive:

$$U := \frac{E(Y)}{YS} = \frac{\eta}{1 + \eta} \cdot [1 - \text{prob}(YD < YS)] \quad (23)$$

The optimal utilization of supply is also completely determined by the variance and the price elasticity of demand, i.e. it is independent from supply and the demand shift parameter  $Z$ .

Now let us turn to the first order condition with respect to employment. The marginal increase of expected output with respect to supply is equal to the probability of the supply constrained regime:

$$\frac{\partial E(Y)}{\partial YS} = \int_{\bar{\varepsilon}}^{\infty} f_{\varepsilon} d\varepsilon. \quad (24)$$

<sup>20</sup>For comparison, see eq. (10) above.

The marginal increase of supply with respect to the employment constraint is given by:

$$\frac{\partial YS}{\partial YL} = 1 - \lambda_{YC} = \begin{cases} 1 & \text{for } YC > YL \\ 0 & \text{for } YC < YL \end{cases}$$

$\lambda_{YC}$  is again the shadow value of capacity constraints. In case of sufficient capacities ( $\lambda_{YC} = 0$ ), an increase of the employment constraint increases supply. For  $YC < YL$ , capacities limit supply, and optimal employment is determined by capacities and the productivity of labour. This implies that output supply is always equal to the employment constraint of the production function: no more workers will be hired than can be employed with the predetermined capital stock. Finally, the marginal increase of the employment constraint of the production function with respect to employment is equal to the productivity of labour  $\pi_l$ . Inserting these expressions into the first order condition, eq. (15), yields:

$$p \cdot \int_{\bar{\varepsilon}}^{\infty} f_{\varepsilon} d\varepsilon \cdot (1 - \lambda_{YC}) \cdot \pi_l - w = 0 \quad (25)$$

The marginal costs of an additional unit of employment are equal to the wage rate  $w$ . Marginal returns are determined as the price, multiplied with the productivity of labour, and multiplied with the probability that the additional unit of output can be sold. For  $\lambda_{YC} = 0$ , the probability of supply constraints is chosen equal to the share of labour costs in full employment nominal output:

$$\int_{\bar{\varepsilon}}^{\infty} f_{\varepsilon} d\varepsilon = \text{prob}(YL < YD) = \frac{w}{p \cdot \pi_l} \quad (26)$$

Figure 2 gives a visual impression of the model.  $f_{YD}$  is the p.d.f. of demand. For small values of  $YL$ , the probability that the marginal unit of labour will be used is large; the marginal return of labour exceeds marginal costs. For higher values of  $YL$ , the probability that demand exceeds supply decreases, and the marginal return of labour decreases. The optimal value of  $\bar{\varepsilon}$  can be determined from

$$\bar{\varepsilon} = F_{\varepsilon}^{-1} \left( 1 - \frac{w}{p \cdot \pi_l} \right) \quad (27)$$

and employment can be determined as:<sup>21</sup>

$$\ln L = -\ln \pi_l + \eta \cdot \ln p + \ln Z + F_{\varepsilon}^{-1} \left( 1 - \frac{w}{p \cdot \pi_l} \right) \quad (28)$$

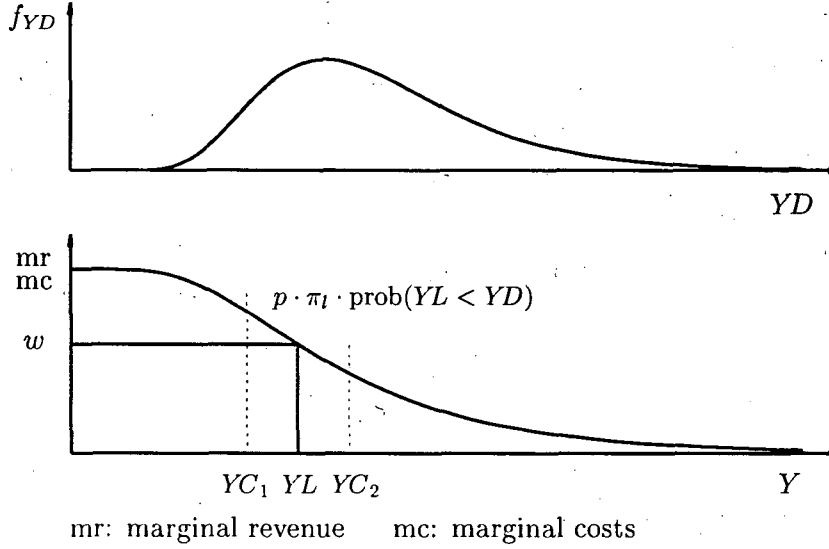
$F_{\varepsilon}^{-1}$  is the inverse of the cumulative distribution function (c.d.f.) of  $\varepsilon$ . Employment is determined via a loglinear relation in terms of the demand shift  $Z$  and the price elasticity of demand  $\eta$ . It depends in a non-linear way on wages, prices, the uncertainty about demand  $\sigma$ , and the productivity of labour.<sup>22</sup>

For the solution of the model, both first order conditions must be combined. The optimal price is achieved by deriving the optimal value of  $\bar{\varepsilon}$  for given  $\sigma$

<sup>21</sup>For comparison, see eqs. (6) and (7) above.

<sup>22</sup>For a detailed discussion, see Smolny (1993).

Figure 2: Optimal employment



and  $\eta$  from eq. (19) above. In case of sufficient capacities (i.e.  $\lambda_{YC} = 0$ ), the optimal price results by inserting eq. (19) into eq. (26) and solving for  $p$ :

$$\ln p = \ln w - \ln \pi_l - \ln [1 - F_\varepsilon(\varepsilon = \bar{\varepsilon})] \quad \text{with} \quad \bar{\varepsilon} = h(\eta, \sigma) \quad (29)$$

Prices are determined by a loglinear function in terms of unit labour costs, and the mark-up depends on the optimal probability of the supply constrained regime. This probability, in turn, is determined completely by the price elasticity of demand and the variance of demand shocks.<sup>23</sup> Prices are independent of demand shifts  $Z$ . The optimal price can also be expressed in terms of the price elasticity of demand, unit labour costs, and the utilization of employment. Rearrangements yield:

$$p = \frac{w}{U \cdot \pi_l \cdot (1 + 1/\eta)} \quad (30)$$

The model without uncertainty is included as a special case: for  $\sigma \rightarrow 0$ , the firm can achieve full utilization of labour and  $U \rightarrow 1$  (see eq. (5) above). Introducing uncertainty lowers the expected (average) utilization of employment, and has the same effect as higher costs. The optimal supply can be determined by inserting eq. (29) into eq. (20) and solving for  $YS$ .

$$\ln YS = \ln Z + h(\eta, \sigma) + \eta \cdot (\ln w - \ln \pi_l - \ln [1 - F_\varepsilon(\varepsilon = \bar{\varepsilon})]) \quad (31)$$

<sup>23</sup> It is mainly determined by the price elasticity of demand  $\eta$  (see eq. (22) above for the weighted probability that supply exceeds demand), but increases with demand uncertainty.



The unconstrained optimal supply is determined via a loglinear function in terms of  $Z$ . It is loglinear with elasticity  $\eta$  in unit labour costs. Optimal employment is given by the corresponding labour requirement. For a normal distribution of  $\varepsilon$ , it can be shown<sup>24</sup> that the optimal price decreases and output and employment increases for increasing  $|\eta|$ . A lower uncertainty about demand at the time of the price and employment decision reduces inefficiencies, lowers the optimal price, and increases output and employment.

In case of capacity (or labour supply) constraints, this optimal value cannot be achieved. In this case, supply is given by capacities  $YC$ ,<sup>25</sup> and the optimal price is determined from eq. (20). The optimal regime probabilities and the utilization of employment  $U$  are in both cases determined from eq. (21–23), i.e. those variables are completely determined by  $\sigma$  and  $\eta$  and are independent from endogenous employment adjustment, demand shifts  $Z$ , and capacity constraints  $YC$ !

The assumption of a delayed adjustment of prices and employment extends the economic interpretations of the model.

- Ex ante, the firm must choose both variables before knowing the location of the demand curve, i.e. there is uncertainty about the demand shock  $\varepsilon$ . The immediate adjustment of prices and employment is contained as a special case for  $\sigma \rightarrow 0$ . As compared with this model, the firm must choose one point in the  $\{p, Y\}$ -diagram (see figure 3). The location of this point is bounded: uncertainty increases the optimal price due to the additional costs of underutilization of labour, i.e. the optimal price always exceeds  $\frac{w}{\pi_1 \cdot (1+1/\eta)}$  and in case of sufficient capacities, optimal employment will be lower.

If capacities are binding, employment is given by the number of workers which can be employed with the capital stock, but prices are still set higher with more demand uncertainty. Note that the optimal utilization of employment and the regime probabilities are independent from capacity constraints.

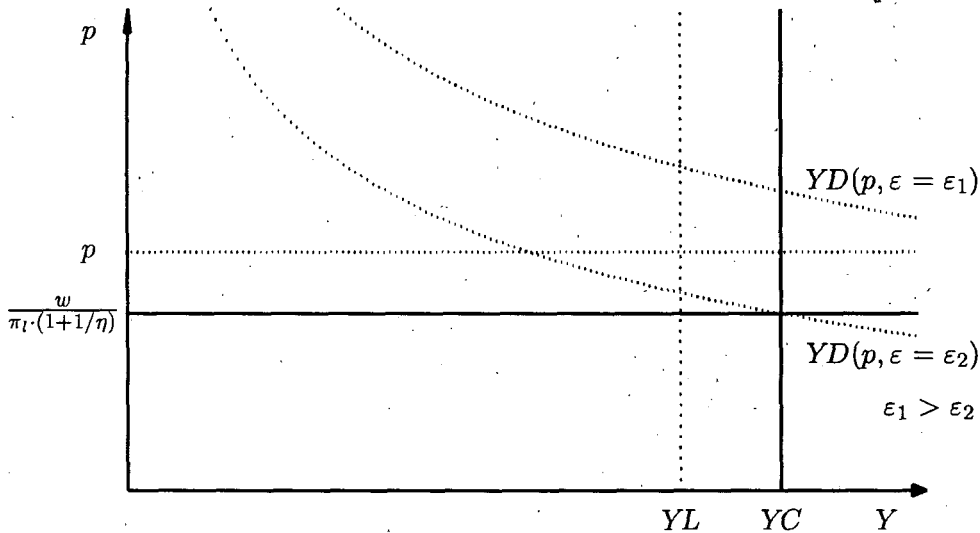
- Ex post, rationing of demand and underutilization of labour and capital is possible. In case of a positive demand shock (e.g.  $\varepsilon = \varepsilon_1$ ), the firm cannot satisfy all customers; in case of a negative demand shock (e.g.  $\varepsilon = \varepsilon_2$ ), labour hoarding occurs.

The model extends the standard deterministic formulation by introducing uncertainty and allows to analyze the resulting inefficiencies. In the model, short-run demand shocks can be identified from the utilization of labour, and the medium-run business cycle situation can be identified from the utilization of capacities. The model also provides a framework to analyze the price and employment adjustment during the business cycle. Consider the case that the

<sup>24</sup>See Smolny (1994).

<sup>25</sup>See figure 2.

Figure 3: Optimal prices and employment



stochastic process generating the demand shocks  $\varepsilon$  is autocorrelated. Then a positive demand shock increases the utilization of supply today. The response of the firm depends on the availability of capacities: in case of capacity constraints, the firm increases the price; in case of sufficient capacities, the price remains constant, and employment increases. That means, the model provides clear testable hypotheses about the effects of capacity utilization (and the business cycle) on the direction and the frequency of changes. A similar asymmetry results in case of cost shocks. If the firm experiences capacity constraints, prices and employment remain unchanged; with sufficient capacities, the firm increases the price and reduces employment.

The dynamic formulation of the model also yields a hypothesis about the effects of changes of the price elasticity of demand and the uncertainty about demand on the output, price, and employment adjustment: an increase of uncertainty  $\sigma$  increases the variance of output and tends to increase the necessity of price and employment adjustments, it becomes more difficult to achieve a high utilization of capacities and employment; a lower price elasticity of demand  $|\eta|$ , on the other hand, favours employment adjustments against price adjustments.

#### 2.1.4 The impact of innovations

The model so far implies a clear testable hypothesis about the price and employment adjustment during the business cycle: prices and employment should increase in case of positive unexpected demand shocks. Indicators of these

demand shocks are the utilization of labour (in case of sufficient capacities)<sup>26</sup> and the utilization of capital. The model also provides a framework to test for the impact of innovations and investment on the price and employment adjustment. Changes of prices and employment depend on changes of supply conditions and changes of the demand curve. The supply conditions are determined by wages and capital costs as well as by investment and own and others' process innovations. Factors affecting the demand curve are the product quality and the prices and the quality of competitors' products.

A successful product innovation implies that the quality of the product increases. In the model, four effects can be distinguished: product innovations can affect the level of demand  $Z$ , the price elasticity of demand  $\eta$ , the uncertainty about demand  $\sigma$ , and/or production costs  $w/\pi_l$ . It is expected that product innovations increase the level of demand for the firm and reduce the competitive pressure from other firms, i.e. demand becomes less price sensitive. Whether demand uncertainty increases or decreases is ambiguous: on the one hand, the firm has less information about the new market and the demand for its product, i.e. the outcome of innovations is uncertain; on the other hand, the firm is better protected from competitive pressure, i.e. demand reacts less with respect to changes of competitors' behaviour.<sup>27</sup> Each of these arguments has a testable implication for the response of the firm:

- if product innovations increase only the level of demand  $Z$ , the response of the firm depends on the availability of capacities. In case of sufficient capacities, the firm should increase output and employment; the price should remain constant. In case of capacity constraints, the price should increase, and output and employment should remain constant.
- if product innovations reduce the absolute value of the price elasticity of demand  $|\eta|$  (i.e. change the market structure), the optimal price increases and the optimal utilization of labour and capital decrease. Whether output and employment increase or decrease depends on the implied level effect on demand. If only  $|\eta|$  decreases, optimal output and employment decrease. A lower price elasticity of demand, in turn, should reduce the variance of prices and increase the variance of employment.
- if product innovations reduce the uncertainty about demand  $\sigma$ , the variance of output is reduced, and it becomes easier to achieve a higher utilization. This reduces the optimal price and increases optimal output and employment. In addition, the necessity of price and employment changes is reduced. The opposite effects hold for an increase of uncertainty.

<sup>26</sup>See eq. (30). With sufficient capacities, the firm adjusts employment to achieve the optimal utilization of labour which in turn depends only on  $\sigma$  and  $\eta$ .

<sup>27</sup>Whether uncertainty increases or decreases when a decision variable is changed is unclear. The future is always uncertain. For a discussion, see Greenwald, Stiglitz (1989). Geroski (1995) found less cyclical pressure for innovative firms.

- if better products are more expensive to produce, the optimal price increases.

That means, product innovations tend to increase prices and the utilization of capacities. Whether output and employment increase depends on the relative importance of the effect on the level of demand and the effect on the price elasticity of demand. A counter-effect on prices could stem from a lower uncertainty about demand shocks. Effects on the variance of prices and employment would indicate effects on the market structure.

Process innovations affect the supply conditions. They reduce marginal production costs through an increase of the factor productivities.<sup>28</sup> Therefore, prices should decrease and output should increase. However, the employment effect of process innovations is ambiguous. On the one hand, more output implies a positive scale effect, on the other hand, process innovations often imply a labour saving technique, i.e. less labour is necessary to produce a given output.<sup>29</sup> For plausible values of the price elasticity of demand, the elasticity of substitution between labour and capital, and the share of labour costs in total costs, the first effect outweighs the second. However, the labour saving property of process innovations is strengthened by its complementarity with capital investment. In most cases, process innovations require at least some capital investment. In addition, it appears plausible that the productivity of process innovations increases with capital investment. Therefore, a firm that implements a process innovation has an incentive to choose a more capital-intensive production technique. A higher capital-intensity and a higher share of capital costs, in turn, are incentives to achieve a higher utilization of capacities.

The effects from capital investment are similar to those from process innovations, but investment also increases capacities  $YC$ .<sup>30</sup> With more capacities, the probability of supply constraints and price increases is reduced, and output should increase. The price effect is strengthened, if capital investment increases the productivity of process innovations and/or reduces production costs. The employment effect of investment is ambiguous. The positive scale effect of more capacities and lower production costs stands against the negative substitution effect of a more capital-intensive production technique. The effect of investment on the utilization of capital is also ambiguous. While investment reduces the probability of capacity constraints, and thereby tends to decrease capacity utilization, a higher capital-intensity and lower labour costs are incentives to achieve a higher utilization.

Firm behaviour also depends on innovations of other firms. If other firms become better, i.e. set lower prices due to lower costs, or offer better products,

<sup>28</sup>Note however that product and process innovations also impose fixed costs.

<sup>29</sup>An induced bias of innovations was analyzed by Kennedy (1964), Weizsäcker (1966), and Samuelson (1965).

<sup>30</sup>It is difficult to disentangle process innovations and investment in quantitative data due to double-counting. See Schankerman (1981). The problem does not occur for our specification of the data, i.e. a dummy for process innovations and quantitative data for investment.

a decrease of demand is expected ( $Z$  decreases). In consequence, output and capacity utilization will decrease. When the firm expects that the demand slowdown is permanent, it will decrease prices and employment. However, innovations of other firms also tend to increase the productivity of own innovations and investment:<sup>31</sup> own innovations and innovations of other firms are complements, if the firm can imitate others' new products or production processes. In addition, lower prices of complementary products increase demand. Nevertheless, these effects tend to reduce the first effect, but probably do not outweigh it.

Finally, innovations change the market structure. As outlined above, product innovations tend to reduce the price elasticity of demand. The intended reduction of the price elasticity may even be the main incentive to implement innovations. In the model, the following implications can be derived:

- first, if markets which are characterized by a large share of product innovators exhibit a lower (in absolute value) price elasticity of demand, prices will be higher and output and employment will be lower. In addition, a lower price elasticity of demand favours employment adjustments against price adjustments.
- second, on markets with a large share of product innovators, demand uncertainty is probably lower since changes in the behaviour of other firms have less effects; the cross price elasticity is reduced. Each firm is protected from its competitors by specialized products. Therefore, the variance of output should be lower, the firms can achieve a higher utilization of capacities, and must change prices and employment less often.
- therefore, sectoral product innovations tend to reduce the variance of prices through both the lower uncertainty of demand shocks and the lower price elasticity of demand. The effect on the variance of employment is ambiguous: the lower uncertainty reduces the variance of employment, but the lower price elasticity of demand tends to increase the variance of employment.

If the market is characterized by a large share of process innovators, the opposite effects are expected. A high intensity of process innovations on a market is probably associated with stronger price competition and a higher price elasticity of demand. Firms try to increase their market share through lower prices. Demand uncertainty is probably higher and it is more difficult to achieve a higher utilization of capacities. Both effects tend to increase the variance of prices, the effect on the variance of employment is again ambiguous. A higher uncertainty of demand increases the variance of employment, but a higher price elasticity of demand favours price adjustments against employment adjustments.

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<sup>31</sup>See Cohen, Levinthal (1989).

**Table 1: Effects of innovations**

	prod	proc	$IY$	prod <sup>s</sup>	proc <sup>s</sup>
$\sigma$	?			-	+
$ \eta $	-			-	+
$Z$	+			-	-
$w/\pi_l$	+	-	-		-

A summary of the expected effects of innovations and investment on the demand curve and on production costs is contained in table 1. A + denotes a positive effect, a - denotes a negative effect, and a ? denotes an ambiguous effect. prod and proc are own product and process innovations,  $IY$  is investment, and the sectoral innovation activities are prod<sup>s</sup> and proc<sup>s</sup>.

## 2.2 Estimation strategy

In the empirical model, it is tested to what extent these arguments can be related to the observed output, price, and employment adjustment. It is tried to explain the adjustment of prices and employment with respect to demand shocks, investment, and innovations. In addition, it is tested for the impact of innovations and investment on output changes and capacity utilization. The theoretical model implies effects on the direction and on the frequency of changes. Both, the data constraint and theoretical considerations inhibit empirical work on the long-run effects on prices and employment and restrict the empirical analysis to the adjustment process: for prices, only qualitative information on the direction of change is available from the data-set. It appears impossible to derive any useful information about the long-run price trend from these data. Furthermore, in the context of product innovations and new products it is difficult to say to what extent any long-run price index would be useful.

The same arguments hold for innovations. Again, the data-set contains only the qualitative information whether a firm has implemented a product or a process innovation.<sup>32</sup> But even if quantitative information on innovation expenditures would be available, the estimation of starting values and depreciation would be difficult. Both for price levels and the stock of knowledge, the measurement errors of long-run levels would be large. Therefore, the model is build to capture the relevant aspects of the adjustment process, and the empirical analysis is constrained to short- and medium-run changes.

<sup>32</sup>Quantitative information on innovations is available for a subset of the data. See Schneeweis, Smolny (1996).

The empirical specification is build on the assumption that firm-specific demand shocks are autocorrelated. The firms exploit this autocorrelation when forming their expectation about demand.<sup>33</sup> This assumption allows to use the degree of utilization today as an indicator for expected product demand tomorrow: there is some value of the expected demand shock, where firms would leave prices and employment unchanged. This value corresponds to a certain (average) degree of utilization. If the actual utilization is higher, the firms should increase prices and/or employment, and vice versa. That means, the specification can be interpreted as a kind of error correction model, and the test of the impact of the capacity utilization rate on the price and employment adjustment provides a test for the appropriateness of this assumption.

The data-set would also allow to distinguish between *high* and *full* utilization of capacities, and to test for the resulting non-linearity of the effect on the price and quantity adjustment. In case of a high utilization of capacities, employment should increase, in case of full utilization only prices should increase. However, empirical data are always aggregations over time and the data on the capacity utilization rate in the data set are classified which makes this distinction less sharp. In addition, labour supply constraints and adjustment costs for employment may restrain the adjustment of employment.

In the empirical analysis, the identification of the model is sought through lagged values of the explanatory variables, i.e. the sequential decision structure of the model is exploited for the estimation. [Table 2](#) summarizes the basic structure of the empirical equations and the theoretical results expected from the model. Endogenous variables are changes of prices  $\Delta p$ , employment  $\Delta L$ , and output  $\Delta Y$ , and the level of the degree of utilization of capital  $DUC$ . In addition, it is tested for effects on their volatility  $\sigma$ . Explanatory variables are own product (prod) and process (proc) innovations, investment  $IY$ , and the sectoral innovation activities (prod<sup>s</sup>, proc<sup>s</sup>). An additional explanatory variable in the equations is the utilization of capacities.

- A high utilization of capacities should lead to an increase of output, prices and employment. In addition, it should increase the variance of prices and reduce the variance of employment and output.
- Own product innovations are expected to increase prices and the utilization of capacities. The impact on output and employment is ambiguous, because the positive level effect on demand may be counteracted by the negative effect from higher prices due to less competition. The effects of own product innovations on the variance of output, prices, and employment are ambiguous.
- Process innovations and investment should reduce costs and prices and thereby increase output. The sign of the employment effect depends on the relative importance of the positive scale effect as compared with the

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<sup>33</sup>That means  $E_{t-\tau}(\varepsilon_t) = \rho \cdot \varepsilon_{t-\tau}$ .

Table 2: Expected effects of innovations

	<i>DUC</i>	prod	proc	<i>IY</i>	prod <sup>s</sup>	proc <sup>s</sup>
$\Delta p$	+	+	-	-	?	-
$\sigma_p$	+	?			-	+
$\Delta L$	+	?	?	?	-	-
$\sigma_L$	-	?			?	?
$\Delta Y$	+	?	+	+	-	-
$\sigma_Y$	-	?			-	+
<i>DUC</i>		+	+	?	?	-

negative substitution effect. Process innovations should increase utilization while the respective effect from investment is ambiguous.

- Product innovations of competitors should reduce output and employment. The effects on prices and utilization are ambiguous: the negative scale effect of lower prices and better products of competitors may be counteracted by market structure effects, i.e. a lower price elasticity of demand and less uncertainty. On markets which are characterized by a large share of product innovators, output and prices should change less often.
- Finally, process innovations of competitors should increase the uncertainty of demand and reduce the level of demand. Output, capacity utilization, prices, and employment should decrease. In addition, output and prices should change more often.

The model provides a framework to test for the impact of innovations on the adjustment of output, prices, and employment. At the same time, it allows to control consistently for short-run demand-induced changes. Prices are allowed to differ from market clearing prices, supply can differ from demand, and underutilization of supply can occur. Therefore, the model should allow to isolate the effects of innovation.



### 3 Empirical analysis

#### 3.1 Data

The data base for the empirical application consists of a panel of West German manufacturing firms for 13 years (1980–92), the ifo firm panel.<sup>34</sup> The data stem from two sources:

- the business survey (Konjunkturtest) of the ifo institute which contains detailed monthly information on the short-run demand and supply conditions. Once a year, the questionnaire includes a question on innovation activities. The answers in the business survey are related to a specific product or product group, i.e. not necessarily to the whole firm. Some firms have different products (groups) in the panel; the panel consists of 2405 observation units from 1982 firms.<sup>35</sup> Most of the data from the business survey are qualitative.
- the investment survey (Investitionstest) of the ifo institute which contains detailed data on investment activities at the firm level. From this survey, the quantitative data on investment, employment, and sales were used.<sup>36</sup> These data are available annually.

Once a year, in december, the business survey contains the information, whether within the year for the respective product an innovation was implemented. Innovations are defined as novelties or essential improvements of the product or the production technique; therefore, innovations should be distinguished from R&D. The answers are distinguished for product and process innovations. The business survey does not contain informations about the number or the relative importance of these innovations.<sup>37</sup>

Figure 4 depicts the frequency distributions for the number of observations (obs), and the relative frequency of product and process innovations. For more

<sup>34</sup>For a detailed description of the data, see Schneeweis, Smolny (1996). The surveys are described in Oppenländer, Poser (1989). I like to thank the ifo Institut, München, for providing the data.

<sup>35</sup>Note that for most firms, the product level corresponds to the whole firm.

<sup>36</sup>The matching of the data was part of the research project "Growth and Innovations". Until recently, most empirical work on innovation with the ifo data base was constrained to the business survey data. See Entorf, Pohlmeier (1990), Zimmermann (1991), Laisney, Lechner, Pohlmeier (1992), Pohlmeier (1992), König, Laisney, Lechner, Pohlmeier (1993), Flaig, Stadler (1994), and Rottmann (1995). Rottmann, Ruschinski (1996) is based on the matched data from the ifo firm panel. A similar data set for Germany is constructed at the ZEW (Zentrum für Europäische Wirtschaftsforschung) in Mannheim. However, the time span is still short, the starting year of the survey is 1993. See Felder, Licht, Nerlinger, Smid (1993).

<sup>37</sup>The ifo firm panel contains, in addition, detailed information on innovation activities from the innovation survey (Innovationstest) of the ifo institute (see Penzkofer, Schmalholz, Scholz (1989)). These data were not employed for the current study; they are available only for a subset of the data base, the response rate of this survey is about 50 percent.

than 800 firms, at least 12 (out of maximal 13) observations are available, additional 500 firms respond at least 10 times. It can be seen that most firms innovate, at least in some years. Only about 400 (from 2405) firms never implemented a product innovation, the respective number for process innovations is slightly above 300. Correspondingly, only about 250 (140) firms implemented a product (process) innovation in each year. The relative frequency of product and process innovations is quite evenly distributed within the range  $\{0, 1\}$ , the average is about 0.5. Table 3 contains time series information on innovations. Apart from the first year, this is the starting year of the question, the share of both product and process innovators is slightly increasing over time.<sup>38</sup>

The business survey also contains quarterly information about employment changes, again for the narrow definition of the product or product group. In four months (january, april, july, and october), the firms are asked, whether the number of employees (seasonally adjusted) will increase, decrease, or stay constant within the next 3 months. On average, 6.6 percent of firms report an increase of employment ( $l^+$ ), 13.7 percent report a decrease ( $l^-$ ), i.e. about 80 percent of the firms report that employment will not change (see table 4).<sup>39</sup>

The investment survey contains a corresponding quantitative information on employment. These data are available annually and only for the firm level. Therefore they cannot be compared directly with the information from the business survey, but they can give some information about the reliability of the qualitative data. Table 3 contains the average employment change ( $\Delta \ln l$ ) as well as its cross-sectional standard deviation  $\sigma$  from the investment survey.<sup>40</sup> It can be seen that the year with the largest employment decrease (1982) is also the year, where most firms report an employment decrease, and the least firms report an employment increase. Correspondingly, in the years with the largest employment increases (1989 and 1990), most firms report an employment increase and the least firms report an employment decrease. The data for total manufacturing depict the same development.<sup>41</sup> That means, at the aggregate level the qualitative and the quantitative data are consistent. Note also the large cross-sectional variance of employment changes, the standard deviation is about 10 percent.

The business survey also contains an information about realized price changes. Every month, the firms are asked whether they had increased, decreased,

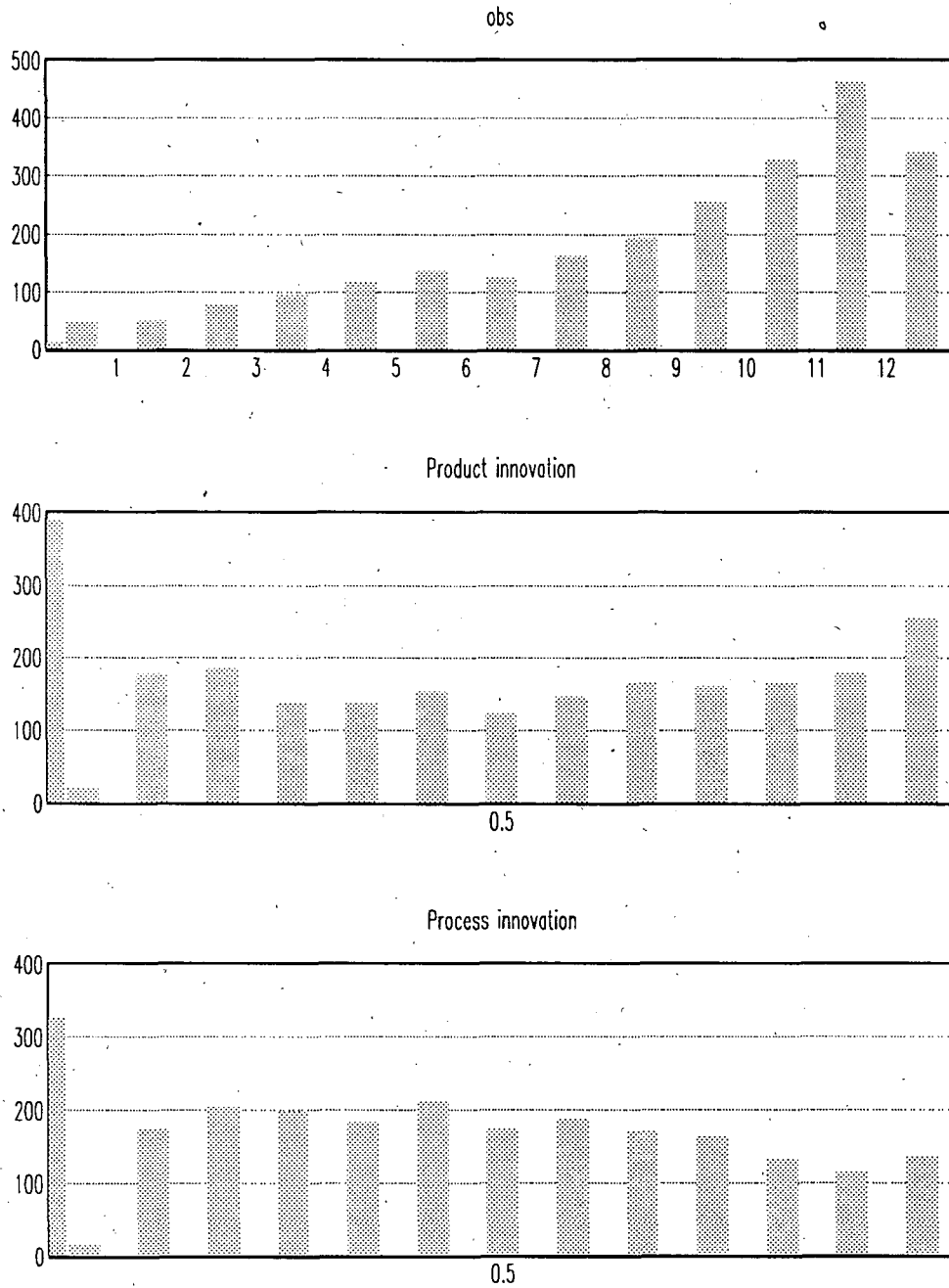
<sup>38</sup>Note the low number of observations for 1980. In table 19 in the appendix, the sectoral shares of innovators are reported. It can be seen that the sectoral variance of the shares exceeds the time series variance.

<sup>39</sup>The respective sectoral data are contained in table 20 in the appendix. Figure 6 in the appendix depicts the distribution of the relative frequency of employment changes for the whole sample, and in table 21, the distribution of employment changes for the months is reported. More than 800 firms never increased employment during the observation period, about 350 firms never decreased employment. A list of variables is contained in table 17 in the appendix.

<sup>40</sup>The sectoral distribution is reported in table 19. In nearly all sectors, employment decreased during the observation period.

<sup>41</sup>See table 22 and table 23 in the appendix.

**Figure 4: Frequency of product and process innovations**



Source: ifo firm panel, 2405 firms, 13 years (1980–92)  
 The first bar denotes 0, the class width is 1 (1/13).

**Table 3: Innovations, investment, employment, and sales**

	prod	proc	obs	$IY$	$\sigma$	obs	$\Delta \ln l$	$\sigma$	obs	$\Delta \ln s$	$\sigma$	obs
1980	0.506	0.496	1007	0.053	0.072	1801						
1981	0.427	0.396	1860	0.044	0.054	1855	-0.025	0.098	1726	0.015	0.132	1724
1982	0.471	0.411	1866	0.041	0.063	1856	-0.044	0.101	1752	0.008	0.137	1756
1983	0.464	0.415	1924	0.042	0.059	1869	-0.033	0.095	1745	0.024	0.134	1749
1984	0.494	0.442	1912	0.043	0.063	1837	-0.011	0.097	1717	0.051	0.136	1718
1985	0.498	0.449	1897	0.047	0.067	1868	0.002	0.105	1696	0.045	0.142	1700
1986	0.493	0.469	1858	0.052	0.069	1877	0.008	0.094	1742	0.029	0.136	1746
1987	0.506	0.463	1766	0.053	0.061	1789	-0.015	0.097	1696	0.000	0.133	1699
1988	0.521	0.494	1736	0.054	0.061	1681	-0.006	0.091	1604	0.053	0.123	1607
1989	0.542	0.519	1710	0.060	0.080	1569	0.020	0.094	1471	0.074	0.124	1471
1990	0.512	0.492	1647	0.063	0.079	1544	0.024	0.097	1440	0.074	0.132	1439
1991	0.533	0.482	1573	0.064	0.084	1434	0.008	0.096	1359	0.049	0.157	1359
1992	0.518	0.479	1481	0.056	0.072	1356	-0.034	0.098	1271	-0.008	0.142	1271
total	0.497	0.459	22237	0.051	0.068	22336	-0.009	0.099	19219	0.034	0.138	19239

**Table 4: Prices, employment, output, and capacity utilization**

	$p^+$	$p^-$	obs	$l^+$	$l^-$	obs	$y^+$	$y^-$	obs	$DUC$	$\sigma$	obs
1980	0.163	0.034	22333	0.068	0.084	7416	0.118	0.179	22342	0.841	0.134	7378
1981	0.148	0.044	23854	0.025	0.193	7866	0.098	0.246	23872	0.805	0.147	7661
1982	0.096	0.080	24660	0.014	0.269	8145	0.097	0.275	24665	0.777	0.152	7884
1983	0.087	0.052	25215	0.030	0.191	8270	0.151	0.182	25239	0.793	0.150	8114
1984	0.123	0.043	25480	0.059	0.123	8363	0.163	0.161	25501	0.813	0.153	8126
1985	0.096	0.042	25625	0.094	0.092	8367	0.159	0.143	25628	0.831	0.148	8188
1986	0.073	0.056	25470	0.082	0.086	8270	0.143	0.148	25477	0.836	0.141	8099
1987	0.071	0.054	24992	0.041	0.136	8125	0.123	0.174	24992	0.826	0.146	7919
1988	0.116	0.030	24190	0.063	0.108	7914	0.165	0.129	24189	0.845	0.136	7646
1989	0.145	0.021	23340	0.133	0.063	7565	0.176	0.100	23341	0.868	0.128	7396
1990	0.134	0.031	22092	0.147	0.051	7215	0.175	0.095	22092	0.882	0.120	6988
1991	0.111	0.049	21276	0.089	0.116	6961	0.127	0.169	21276	0.862	0.122	6741
1992	0.075	0.090	20510	0.026	0.269	6694	0.090	0.263	20507	0.822	0.134	6460
total	0.110	0.048	309037	0.066	0.137	101171	0.138	0.174	309121	0.830	0.143	98600

Source: Ifo firm panel, 2405 firms, 13 years

or left unchanged their prices (net prices) as compared with the last month. On average, 11 percent report that they have increased their prices ( $p^+$ ), 4.8 percent report that they have decreased their prices ( $p^-$ ); more than 80 percent report unchanged prices (see table 4). That means, on average there is about one price increase each year for each product, and about one price decrease every second year.<sup>42</sup> However, the distribution is quite uneven: nearly 1000 firms never reported falling prices during the observation period, and a large number of firms do not report any price change during some years.<sup>43</sup> The rather low frequency of price changes (on average less than 2 changes a year) is consistent with the assumption of price tags applied for the model. The high frequency of the observations (monthly), on the other hand, should allow to test for effects of innovations on the volatility of price changes.

The business survey information on output changes corresponds to those on price changes: every month, the firms are asked whether they had increased, decreased, or left their output constant. On average, 13.8 percent report an increase of output ( $y^+$ ), 17.4 percent report a reduction of output ( $y^-$ ), i.e. output changes were more frequent than price changes (see table 4).<sup>44</sup> This is again consistent with the assumptions applied for the model.

For each, prices and output no quantitative information is available at either the firm or the product level. However, the investment survey contains an annual information about sales at the firm level. The corresponding average rate of change ( $\Delta \ln s$ ) and its cross-sectional standard deviation are reported in table 3. Therefore, it is possible to test to what extent the qualitative monthly price and output information at the product level together correspond to the annual information on sales at the firm level. In table 5, some results of least squares regressions of quantitative sales changes on qualitative price and output changes are reported. The table also includes the corresponding regression results for employment.

In the first row, the logarithmic change of employment at the firm level  $\Delta \ln l$  is regressed on the relative number of employment increases  $\bar{l}^+$  and the relative number of employment decreases  $\bar{l}^-$  at the product level within the year. The equation implies the compounded test that the product level data correspond to the firm level data and that the qualitative data correspond to the quantitative changes. Both variables are highly significant with the expected sign. In addition, the absolute value of both coefficients is nearly identical. The coefficients imply that

- the growth rate of employment for a firm that reported an employment increase (decrease) in each quarter is 10 percent higher (lower) than those of a firm that reported no employment changes,

<sup>42</sup>These frequencies correspond to those reported by Blinder (1991) for the U.S..

<sup>43</sup>See table 7 below and figure 7 and table 20 in the appendix. For 8406 (about 30 percent) observations (firms times years) we observe no price change within the year.

<sup>44</sup>See also figure 8 and table 20 in the appendix.

**Table 5: Correlation between qualitative and quantitative data**

endogenous variable: employment changes  $\Delta \ln l$

const.	$\bar{l}^+$	$\bar{l}^-$	$l1^+$	$l1^-$	SEE	$\bar{R}^2$	obs
-0.002 (-2.2)	0.101 (25.2)	-0.102 (-37.5)			0.093	0.117	18030
-0.002 (-1.8)			0.050 (25.5)	-0.054 (34.7)	0.093	0.109	18030
-0.001 (-1.6)	0.054 (6.9)	-0.074 (-14.8)	0.026 (6.7)	-0.018 (-6.3)	0.093	0.121	18030

endogenous variable: sales changes  $\Delta \ln s$

const.	$\bar{y}^+$	$\bar{y}^-$	$y1^+$	$y1^-$	$\bar{p}^+$	$\bar{p}^-$	$p1^+$	$p1^-$	SEE	$\bar{R}^2$	obs
0.044 (26.0)	0.097 (17.0)	-0.150 (29.5)			0.059 (8.8)	-0.067 (-9.0)			0.132	0.082	18247
0.044 (19.6)			0.034 (16.9)	-0.052 (-24.9)			0.016 (7.8)	-0.027 (-10.5)	0.133	0.060	18247
0.046 (20.7)	0.082 (10.2)	-0.121 (-17.9)	0.010 (3.5)	-0.018 (-6.4)	0.048 (5.8)	-0.037 (-3.4)	0.005 (2.0)	-0.012 (-3.3)	0.131	0.085	18247

Note: OLS-estimates, sample 1981-1992

- i.e. each reported employment increase implies a 2.5 percent higher growth rate of employment, each reported employment reduction implies a 2.5 percent lower growth rate of employment.

The results for sales are similar: qualitative output and price changes are significantly correlated to quantitative sales changes with the expected sign. Each monthly reported output change corresponds to an about one percent change of sales, each monthly reported price change corresponds to an about 0.5 percent change of sales.

In the next rows, it is tested for a non-linearity of the relation between qualitative changes and quantitative changes.  $l1^+$ , ( $l1^-$ ) is a dummy variable that takes the value 1, if the firm reported an employment increase (decrease) at least once a year, the price and output variables are defined correspondingly.<sup>45</sup> It can be seen that this specification of the qualitative answers contains less information about the quantitative changes. However, it contains an additional information. For instance, increasing employment in each quarter implies less than four times the effect of increasing employment once a year. Taken together, it can be concluded that the qualitative information on employment, prices, and output appears to be reliable.

The business survey also contains quarterly information on the degree of capacity utilization *DUC* (from march, june, september, and december). The

<sup>45</sup>For the observed frequency of price, output, and employment changes, see table 7 below.

averages and the cross-sectional standard deviations are reported in table 4.<sup>46</sup> The average utilization is 83 percent, the standard deviations is about 14 percent. This low utilization is again consistent with the model and underlines the importance to control for short-run demand induced effects. Finally, in table 3 the share of investment in sales from the investment survey is reported. Notable is both the cyclical variance, but also the much higher cross-sectional variance.

In figure 5, time series plots of the data on prices, output, employment, and capacity utilization are depicted. In the first three figures, the solid line represents the share of firms reporting an increase of the respective variable, the dotted line represents a decrease. In the figure at the bottom, capacity utilization (solid line) is plotted together with  $\pm$  one standard deviation (dotted lines). It can be seen that the observation period captures slightly more than one business cycle. 1980 was the first year of a beginning downturn, 1990 was about the last year of the following upswing. The sample ends with the deep recession in 1992; the short downswing in 1987 is hardly visible in the data. Remarkable is also the seasonal figure of price increases (not decreases) which take place mostly in the first half of the year, especially in january.<sup>47</sup> Employment changes appear to be smoother, although one has to keep in mind that only quarterly data are available.

### 3.2 Attrition

An important topic when dealing with cross sectional-data is a possible sample selection bias.<sup>48</sup> For the ifo firm panel, three sources of endogenous sample selection can usefully be distinguished:

- The firms in the panel are not representative for the whole population: actually, small firms are underrepresented while large firms are strongly oversampled as compared with total manufacturing. This should not be a problem, but it should be hold in mind when interpreting the results. In addition, if results for small and large firms differ significantly, it is possible to re-estimate the equations for sub-samples.<sup>49</sup>

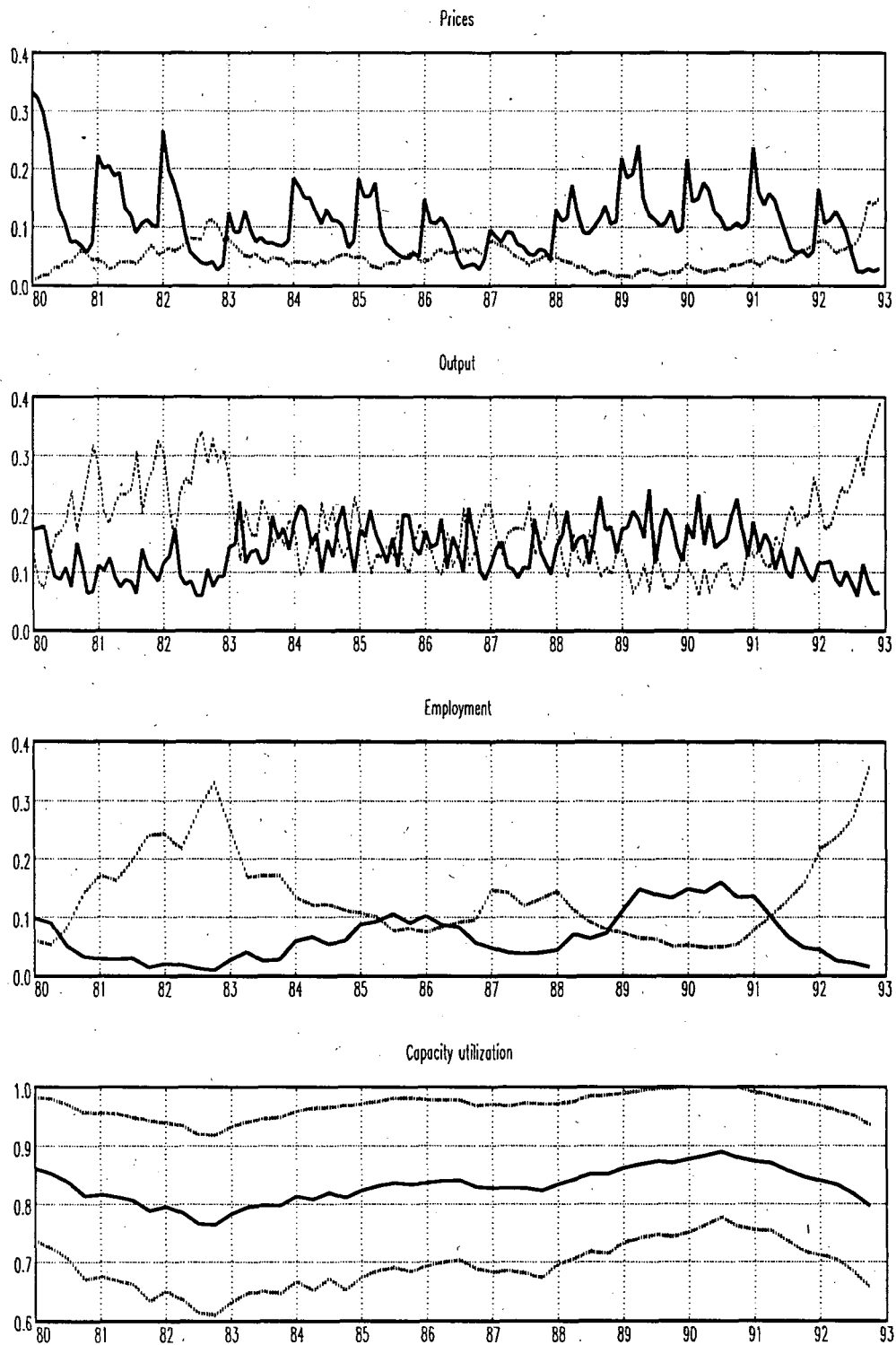
<sup>46</sup>The data are classified in steps of 5 percent from 30 percent to 100 percent. For about 15 percent of the observations the degree of utilization of capacities is 100 percent. The firms can also report a capacity utilization rate above 100 percent. This is the case for 2 percent of the observations. For the estimations, the data were truncated at 100 percent.

<sup>47</sup>See also table 21 in the appendix.

<sup>48</sup>See Heckman (1979). An overview is given by Verbeek, Nijman (1995).

<sup>49</sup>See Schneeweis, Smolny (1996). The sectoral distribution of firms in manufacturing is captured quite accurately in the panel (see table 18 in the appendix). The annual and cross-sectoral means of the quantitative variable are also consistent with the corresponding figures for total manufacturing. See table 19, 22, and 23 in the appendix. Another possible source of endogenous sample selection is that innovators may be over-represented. However, this concerns mostly surveys which put most emphasis on the innovation question, for instance the innovation survey of the ifo institute. In the business survey of the ifo institute, innovation is only one topic among many.

Figure 5: Prices, output, employment, and capacity utilization



Source: ifo firm panel



- Another source of endogenous sample selection is that the probability of missing data for specific variables is correlated with the variables of the model. For instance, the probability to fill out the question on innovation may be higher for innovators. However, for our data-set, the response rate for each question is rather high. In addition, non-responders for the question on innovation report about the same values for other business survey variables as responders.<sup>50</sup>
- Probably the most important endogenous selection problem for the ifo firm panel data is attrition. Since the panel covers a rather long period, a large number of firms left the panel during the observation period: In 1980, 2156 firms (products) participated in the panel. Since then, 243 firms entered the panel, while 548 firms left it. Therefore, in 1992, there were 1851 firms left. The annual attrition rate since 1985 is about 3.5 percent.<sup>51</sup>

Attrition is not random. For instance, every year about 2 percent of all firms in manufacturing were closed due to insolvency.<sup>52</sup> Other firms were liquidated or they stopped producing specific products. Of course, not all exits out of the panel are also exits out of the market, some firms probably left the panel for other reasons. Nevertheless, the possible endogeneity of attrition should be taken into account. In table 6, some results for a selection equation are reported. The endogenous variable is a dummy which is one, if the firm leaves the business survey in the current year. Explanatory variables are the same as those for the economic model;<sup>53</sup> they refer to the preceeding year. Whether a firms leaves the panel in the last year is unknown, therefore the endogenous variable is not defined for this year. In the first rows, the share of investment in sales is included. Since the timing of the investment survey and the business survey is different, investment data for many leavers are missing.<sup>54</sup> Therefore, the equations are also estimated without this variable.

The results show clearly the endogeneity of attrition. First, a high degree of capacity utilization significantly reduces the probability of leaving the panel. This confirms the hypothesis that at least some firms leave the panel due to exit out of the market. Second, implementing an innovation reduces the probability

<sup>50</sup>The response rate nearly is 90 percent for the question on innovation, and above 99 percent (at an annual base) for the monthly questions on prices and output. A sample selection correction (Heckman) for response/non-response did not prove significant for the model equations.

<sup>51</sup>Figure 9 and table 24 in the appendix depict the entries and exits for the panel. 6 firms which participated for less than 7 months were excluded. Before 1984, attrition is very low. The reason is that for firms leaving the business survey before 1985 the business survey could not be matched with the investment survey. Therefore, those data were excluded for the analysis here. However, business survey information is available also for those firms.

<sup>52</sup>See Winker (1996).

<sup>53</sup>That means, it is tested to what extent the attrition selection is correlated with the explanatory variables of the model.

<sup>54</sup>The investment survey is in summer and refers to the last year.

**Table 6: Endogenous attrition**

endogenous variable: leaving the panel, exit							
<i>DUC</i>	prod	proc	<i>IY</i>	prod <sup>s</sup>	proc <sup>s</sup>	$\bar{l} < 50$	$\bar{l} > 1000$
-1.379	-0.141	-0.040	-0.492	0.367	-0.334	0.016	-0.211
(-6.7)	(-2.1)	(-0.6)	(-1.0)	(1.4)	(-0.9)	(0.2)	(-2.5)
-1.342	-0.130	-0.115		0.749	-0.971	0.005	-0.223
(-8.0)	(-2.5)	(-2.2)		(3.5)	(-3.1)	(0.1)	(-3.2)

Notes: binary probit models,  
sample: 1981-1991, time dummies for 1984-1991 were included.

of leaving the panel. Third, product innovations of competitors increase the probability of leaving the panel, process innovations reduce it. prod<sup>s</sup> and proc<sup>s</sup> are the shares of innovators in the sector. Note that the sector means are calculated excluding the respective firm. Finally, large firms with more than 1000 employees ( $\bar{l} > 1000$ ) leave the panel less often. This is again consistent with the view that leaving the panel is correlated with leaving the market.

One possibility to deal with endogenous attrition for the estimation of the model is to estimate the economic model with a sample selection correction. However, in our case a serious identification problem arises, since selection is affected by the same factors as the endogenous variables of the economic model. Selection can be seen like a kind of truncation for some of the endogenous variables (employment, sales, utilization): at some stage, it is not profitable to stay in the market. Another possible test for the impact of attrition on the model parameters is to include a dummy variable for future leavers of the panel.<sup>55</sup> This corresponds to the view that selection (attrition) can be treated like a fixed effect, e.g. general bad business prospects of the product or a bad management. Since dealing with endogenous attrition within a simultaneous equation context does not appear feasible due to the identification problem, the second procedure is chosen here: dummy variables for future leavers and exits are included in all model equations. The results are discussed below. Note that this procedure does not "solve" the selection problem entirely. It does not yield unbiased parameters for the model, since attrition is an endogenous variable.<sup>56</sup> Nevertheless, it gives an impression about the importance of the sample selection problem for the model parameters.

<sup>55</sup>The difference between both model refers to the distinction selection by observables versus selection by unobservables.

<sup>56</sup>See Heckman, Hotz (1989). Since nearly all variables from the data base are more or less related to the business conditions of the firm, an instrumental variable technique also does not solve the identification problem.

### 3.3 Empirical specification

On the following pages, the estimation results for prices, employment, output, and capacity utilization are presented. For the qualitative variables from the business survey (prices, output, and employment), different specifications are employed.

- first, binary probit models for increases and decreases for each month are estimated. This sums up to, in total, 24 equations for prices and output, respectively, and to 8 (quarterly) equations for employment.<sup>57</sup>
- second, annual data were constructed. Dummy variables are specified for an increase or decrease at least once a year and more than once a year. For instance, for about 40 (80) percent of the annual observations, the firms did not report any increase (decrease) of prices during the year. The corresponding shares for employment are both about 80 percent (see table 7).
- third, net increases (i.e. number of increases *minus* number of decreases) are calculated from the annual data. From these data, dummy variables are constructed for positive and non-negative net increases. In addition, the relative (to the available number of observations per year) number of net increases is used as a quantitative variable.<sup>58</sup>
- fourth, a measure of volatility is calculated as the number of changes (number of increases *plus* number of decreases) within the year. For the estimation, dummy variables are constructed for no change within the year and more than one change during the year, since the number of changes exhibits a strongly skewed distribution.<sup>59</sup> Note especially the large number of observations with no change (see table 7).

For the quantitative data on capacity utilization, tobit models both for each quarter and for the annual average are estimated; the variable is truncated at both ends: capacity utilization cannot exceed full utilization (100 percent),<sup>60</sup> and the questionnaire does not allow to report a capacity utilization below 30 percent. The quantitative annual variables from the investment survey, i.e. employment changes and sales changes were estimated by OLS.

<sup>57</sup>A system estimation or a multinomial probit model is more efficient. However, a large share of firms always reported no change of the variable (about 80 percent). Therefore, the efficiency gain from system estimation is expected to be small. In addition, the sample is quite large, even for only one observation per year.

<sup>58</sup>Note that this kind of balancing is not without problems; relevant information may be lost. However, it was shown above that the number of increases and decreases captures quite well the development of the quantitative changes. In addition, the different specifications of the variables should reveal information losses.

<sup>59</sup>The specification for output refers to more than one change every second month.

<sup>60</sup>For about 15 percent of the observations the degree of utilization of capacities is 100 percent. In 2 percent, firms report a capacity utilization above 100 percent; for the estimations, the data were truncated at 100 percent.

Table 7: Frequency of price, output, and employment changes

freq	increase	decrease	no change	change	obs
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prices

0	11468	22807	201	8406	3196
1	9017	2088	371	9087	172
2	3849	1045	471	4429	168
3	1535	662	566	2092	219
4	831	435	707	1215	268
5	458	339	925	856	301
6	305	222	1144	606	412
7	190	180	1492	436	472
8	131	113	1993	301	612
9	105	89	3007	262	995
10	85	52	4814	195	1796
11	48	25	7282	109	4140
12	47	12	5096	75	18514

net increases

	ps	ys	ls
-12	12	52	
-11	24	52	
-10	45	84	
-9	78	157	
-8	97	220	
-7	142	380	
-6	186	588	
-5	272	804	
-4	330	1169	601
-3	517	1697	1094
-2	779	2540	1881
-1	1373	3723	3867
0	9049	7634	16269
1	8348	3358	2454
2	3523	2121	935
3	1373	1397	420
4	695	844	158
5	400	552	
6	264	279	
7	168	196	
8	116	94	
9	100	59	
10	84	41	
11	47	20	
12	47	8	

output

0	12369	10290	447	5400	3196
1	5212	5079	744	3780	172
2	3586	3924	1053	3482	168
3	2548	2937	1496	3184	221
4	1771	2143	1752	2901	263
5	1225	1497	2198	2585	305
6	677	951	2397	2038	409
7	363	575	2760	1669	468
8	164	280	2891	1210	612
9	79	196	2833	878	1001
10	44	92	2942	507	1779
11	23	53	2944	299	4104
12	8	52	3612	136	18567

employment

0	23307	19833	1341	15956	3586
1	2770	4184	2939	6168	869
2	1012	1950	4404	3089	1397
3	432	1111	7099	1667	4144
4	158	601	11896	799	21269

Source: ifo firm panel

Explanatory variables are capacity utilization, investment, and own and others' product and process innovations. All equations include two size dummies for firms with less than 50 employees ( $\bar{l} < 50$ ) and for firms with more than 1000 employees ( $\bar{l} > 1000$ ) on average, i.e. medium size firms with 50 to 1000 employees are the reference group. In addition, a complete set of 11 time dummies is always included (not reported). These dummies shall capture effects from wages and prices of raw materials and intermediates; the data set does not include information about those variables.<sup>61</sup> Finally, all equations are tested for sample selection bias due to endogenous attrition by including dummies for leavers or exits in the next periods.<sup>62</sup>

Since the explanatory variables are also endogenous, the identification of the model is sought through lagged values of the explanatory variables. The theoretical model implies a clear sequential decision structure for all variables which is exploited for the estimates. For the monthly price equations and the quarterly employment equations, capacity utilization is taken from the preceding quarter, e.g. price changes from january until march and planned employment changes from january (for the next three months) are related to capacity utilization from december last year. For the annual variables, capacity utilization is specified as the average of the last year. The annual observations on investment and innovation were always taken from the last year. Therefore, the estimates from the monthly and quarterly data should also give some information about the length of the adjustment delays. The identification of the model through lags of the explanatory variables in panel data is disputable in case of autocorrelation. However, the model implies a clear recursive structure, and the endogenous variables are already specified as changes.

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<sup>61</sup>Using the available sectoral data on average wages is also questionable. Inter-industry wage differentials approximate to a large extent inter-industry differences in labour qualification and therefore do not measure labour costs correctly. See Krueger, Summers (1988), Smolny (1995) and Mulligan, Sala-i-Martin (1995). The estimated model corresponds to the assumption that wages and other input costs are the same for all firms, apart from those differences captured by the dummies (time, size).

<sup>62</sup>The robustness of the results was also tested with 27 sector dummies and with a fixed effects (linear probability) model. The general conclusion of these estimates was that the qualitative results for the firm specific variables do not differ, but the sectoral variables became less significant (not reported). This was expected, since these variables should approximate the market structure which changes only slowly over time. A random effects model was not estimated, since the required assumption of uncorrelatedness of the random effects and the explanatory variables does not appear plausible. Note also that the endogenous variables are already specified as changes.

### 3.4 Estimation results

#### 3.4.1 Prices and employment

In table 8 and table 9, the estimation results for price increases and price decreases are reported. From the theoretical model, a positive effect from capacity utilization and product innovations on prices is expected. Process innovations and investment should reduce costs and lead to lower prices. Process innovations of competitors should lead to lower prices due to increased competitive pressure; the effect from a large share of product innovators on prices is ambiguous.

The results, in general, confirm the theoretical model. First, a highly significant positive effect from capacity utilization on the probability of price increases is found. The value of the coefficients is higher in the second half of the year, but note that the probability of a price increase is higher in the first half of the year. Correspondingly, the probability of price decreases is significantly reduced by a high capacity utilization. This effect appears to be stronger in the first half of the year. Surprisingly, the effect on price decreases is less clear, if the endogenous variable is specified annually, i.e. as a decrease at least once a year or more than once a year. Note however that in this case the capacity utilization rate refers to the last year, not to the last quarter. Perhaps a price reduction follows rather closely on a lower utilization of capacities.<sup>63</sup>

In table 10, the results for the net price increases and for the volatility of prices are reported. The results for the net increases are consistent with those above, i.e. capacity utilization increases the probability of net price increases ( $ps > 0$ ) and the relative number of net increases ( $ps/obs$ ), but does not affect significantly the probability of net price reductions. The results for volatility reveal that a high capacity utilization increases the probability that the firm will change prices at least once ( $pc > 0$ ) or more than once ( $pc > 1$ ), respectively. That means, the volatility of prices is higher in case of a high utilization of capacities which is consistent with the model: in case of a high capacity utilization, quantity adjustments are restricted and positive demand shocks affect prices.

Product innovations tend to increase the probability of a price increase, decrease the probability of a price decrease, and consequently increase the probability of positive (non-negative) net price increases. Here, the effect on price decreases exceeds the effect on price increases, i.e. product innovations tend to decrease the volatility of prices. The effect on price increases is strongest in the first months of the year. The price effect of product innovations is robust with respect to the specification of the endogenous variable. Note that this result already indicates that product innovations reduce competitive pressure on prices, i.e. reduce the price elasticity of demand. A simple demand shift should lead to an increase of output and employment and should leave prices

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<sup>63</sup>The results are qualitatively the same, if the endogenous variable is specified as the relative number of price increases or decreases within the year (not reported).

unchanged. However, it is not clear yet, to what extent this effect is also caused by higher production costs of a better product. A look on the effect on price changes shows that product innovations increase the probability that the price is changed at least once a year, but reduce the probability that the price is changed more than once a year.<sup>64</sup> These results permit the interpretation that product innovating firms mostly increase prices once a year which is consistent with the conventional view of the price-setting on monopolistic markets.

Surprisingly, the estimations do not show a conclusive effect from process innovations on the price setting. From the theoretical model, a price reduction is expected. Process innovations should reduce marginal costs and therefore prices. For the probability of price increases, only at the end of the year a significant negative effect is found. A similar inconclusive result is revealed for the share of investment in sales  $IY$ . Investment should reduce the probability of price increases and should increase the probability of price decreases. The sign of the respective coefficients is correct in most cases, but the effect is hardly significant. One reason for the inconclusive results could be that it takes some time before cost reductions affect prices. At first, firms try to capture the fixed costs of process innovations and investments by a prolonged period of higher prices. The more conclusive results for the second half of the year support this hypotheses. Another reason could be the multicollinearity of process innovations and investment. For instance, the average share of investment in sales for process innovators is 0.056, compared with 0.047 for firms that do not innovate.

The share of product innovators in a sector ( $prod^s$ ) exhibits a very strong and significant effect on the price setting behaviour of the firms.<sup>65</sup> Being in a sector with a high share of product innovators decreases both the probability of price increases and the probability of price decreases. Firms in innovative sectors change prices less often! This result is confirmed by the estimates for the volatility of prices.<sup>66</sup> This is another hint that product innovations significantly affect the market structure. In those sectors price competition is displaced by specialization, or price competition is displaced by competition in innovation behaviour. Each firm produces a specific product and is protected from the behaviour of other firms. Therefore, the volatility of demand is lower and/or the price elasticity of demand is lower and prices are less often adjusted. Note that a reduction of the probability of price increases is not revealed, if the endogenous variable is defined as an increase at least once a year. That means, a high share of product innovators in the sector reduces the *number* of price increases, but not the *probability* of price increases within the year.

The results also indicate that the net effect on prices is positive. The effect on the probability of price decreases is stronger than on the probability of price

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<sup>64</sup>In table 25, the results for the reduced form estimates (i.e. where the capacity utilization rate is omitted) are reported. They give roughly the same impression.

<sup>65</sup>Note that the sector mean is always calculated excluding the respective firm.

<sup>66</sup>The reduction of the variability of prices is also highly significant for the relative share of each, price increases and price decreases within a year (not reported).

**Table 8: Price increases**

endogenous variable: price increase, $p^+$								
month	<i>DUC</i>	prod	proc	<i>IY</i>	prod <sup>s</sup>	proc <sup>s</sup>	$\bar{l} < 50$	$\bar{l} > 1000$
jan	0.309 ( 3.5)	0.165 ( 6.0)	-0.008 (-0.3)	-0.199 (-1.0)	-0.072 (-0.7)	0.429 ( 2.7)	-0.104 (-2.5)	0.074 ( 2.5)
feb	0.331 ( 3.6)	0.093 ( 3.2)	0.006 ( 0.2)	-0.123 (-0.6)	-0.203 (-1.8)	0.061 ( 0.4)	-0.185 (-4.1)	0.034 ( 1.1)
mar	0.499 ( 5.2)	0.028 ( 0.9)	0.009 ( 0.3)	0.118 ( 0.6)	-0.311 (-2.7)	-0.247 (-1.5)	-0.097 (-2.2)	-0.038 (-1.2)
apr	0.432 ( 4.5)	-0.011 (-0.4)	0.031 ( 1.1)	0.064 ( 0.3)	-0.716 (-6.2)	0.584 ( 3.5)	0.001 ( 0.0)	0.009 ( 0.3)
may	0.665 ( 6.3)	-0.075 (-2.4)	0.004 ( 0.1)	-0.045 (-0.2)	-0.958 (-8.0)	0.581 ( 3.3)	0.006 ( 0.1)	-0.145 (-4.1)
jun	0.644 ( 5.6)	-0.010 (-0.3)	0.007 ( 0.2)	0.039 ( 0.2)	-1.180 (-9.0)	0.205 ( 1.1)	-0.118 (-2.4)	-0.174 (-4.5)
jul	0.817 ( 6.6)	0.022 ( 0.6)	-0.052 (-1.5)	-0.322 (-1.3)	-0.850 (-6.2)	-0.493 (-2.4)	-0.014 (-0.3)	-0.023 (-0.6)
aug	0.757 ( 5.8)	-0.067 (-1.7)	0.021 ( 0.5)	-0.556 (-1.9)	-0.857 (-5.8)	-0.517 (-2.4)	-0.058 (-1.0)	0.044 ( 1.0)
sep	0.734 ( 5.7)	-0.006 (-0.1)	-0.005 (-0.1)	-0.377 (-1.4)	-0.826 (-5.6)	-0.570 (-2.7)	-0.031 (-0.6)	0.050 ( 1.2)
oct	0.718 ( 5.8)	-0.005 (-0.1)	-0.057 (-1.6)	-0.292 (-1.2)	-0.613 (-4.3)	-0.198 (-1.0)	0.000 ( 0.0)	0.122 ( 3.2)
nov	0.900 ( 6.6)	0.053 ( 1.4)	-0.045 (-1.2)	0.221 ( 0.9)	-0.360 (-2.4)	-0.495 (-2.2)	-0.036 (-0.6)	0.032 ( 0.8)
dec	0.749 ( 5.8)	0.108 ( 2.9)	-0.091 (-2.5)	-0.514 (-1.8)	-0.250 (-1.7)	-0.393 (-1.8)	-0.030 (-0.6)	0.050 ( 1.2)
endogenous variable: price increase at least once a year, $p1^+$								
	0.369 ( 4.5)	0.139 ( 6.0)	0.053 ( 2.3)	-0.267 (-1.7)	0.082 ( 0.9)	0.384 ( 2.8)	-0.181 (-5.6)	-0.040 (-1.6)
endogenous variable: price increase more than once a year								
	0.705 ( 7.7)	0.049 ( 2.0)	-0.001 (-0.0)	-0.414 (-2.3)	-0.744 (-7.7)	-0.043 (-0.3)	-0.098 (-2.7)	0.022 ( 0.8)

Notes: binary probit models,  
sample: 1981-1992, time dummies (1981-1991) were included



Table 9: Price decreases

endogenous variable: price decrease, $p^-$								
month	<i>DUC</i>	prod	proc	<i>IY</i>	prod <sup>s</sup>	proc <sup>s</sup>	$\bar{i} < 50$	$\bar{i} > 1000$
jan	-0.470 (-4.0)	-0.237 (-5.6)	-0.026 (-0.6)	-0.128 (-0.5)	-1.425 (-9.2)	-0.123 (-0.5)	0.121 (2.4)	0.217 (4.8)
feb	-0.519 (-4.3)	-0.237 (-5.5)	0.071 (1.7)	-0.460 (-1.5)	-1.267 (-8.1)	-0.239 (-1.0)	0.193 (3.8)	0.105 (2.2)
mar	-0.619 (-5.1)	-0.235 (-5.4)	0.039 (0.9)	-0.310 (-1.0)	-1.191 (-7.4)	0.084 (0.4)	0.084 (1.6)	0.118 (2.5)
apr	-0.760 (-6.1)	-0.167 (-3.9)	-0.014 (-0.3)	-0.191 (-0.7)	-1.305 (-8.1)	0.179 (0.7)	0.012 (0.2)	0.007 (0.1)
may	-0.549 (-4.2)	-0.116 (-2.7)	-0.078 (-1.8)	0.318 (1.3)	-1.430 (-8.8)	-0.071 (-0.3)	0.000 (0.0)	0.083 (1.7)
jun	-0.387 (-3.0)	-0.121 (-2.9)	-0.027 (-0.7)	0.366 (1.5)	-1.705 (-10.7)	0.419 (1.7)	-0.029 (-0.5)	0.097 (2.1)
jul	-0.660 (-5.0)	-0.197 (-4.5)	0.009 (0.2)	0.369 (1.5)	-1.811 (-11.0)	0.759 (3.1)	0.005 (0.1)	0.180 (3.8)
aug	-0.213 (-1.6)	-0.223 (-5.0)	0.041 (1.0)	0.313 (1.2)	-1.530 (-9.2)	0.313 (1.3)	-0.021 (-0.4)	0.114 (2.3)
sep	0.011 (0.1)	-0.187 (-4.4)	0.132 (3.3)	0.163 (0.7)	-1.472 (-9.4)	0.373 (1.6)	0.058 (1.1)	0.022 (0.5)
oct	-0.327 (-2.6)	-0.198 (-4.8)	0.049 (1.2)	0.144 (0.6)	-1.943 (-12.6)	0.764 (3.3)	0.055 (1.0)	0.069 (1.5)
nov	-0.311 (-2.5)	-0.134 (-3.3)	-0.039 (-1.0)	0.458 (2.0)	-1.773 (-11.6)	0.615 (2.7)	0.077 (1.5)	0.078 (1.7)
dec	-0.195 (-1.5)	-0.136 (-3.2)	-0.025 (-0.6)	0.431 (1.8)	-1.684 (-10.7)	0.598 (2.6)	0.136 (2.5)	0.234 (5.2)
endogenous variable: price decrease at least once a year, $p1^-$								
	0.000 (0.0)	-0.174 (-6.5)	-0.004 (-0.1)	0.126 (0.7)	-1.584 (-15.4)	0.164 (1.1)	0.108 (3.0)	0.115 (3.8)
endogenous variable: price decrease more than once a year								
	-0.012 (-0.1)	-0.188 (-6.1)	-0.004 (-0.1)	0.025 (0.1)	-1.774 (-15.2)	0.119 (0.7)	0.127 (3.2)	0.161 (4.7)

Notes: binary probit models,  
sample: 1981-1992, time dummies (1981-1991) were included

**Table 10: Price changes**

	<i>DUC</i>	prod	proc	<i>IY</i>	prod <sup>s</sup>	proc <sup>s</sup>	cat <sub>1</sub>
ps > 0	0.383 ( 4.6)	0.168 ( 7.3)	0.043 ( 1.9)	-0.185 (-1.2)	0.523 ( 5.8)	0.167 ( 1.2)	0.538
ps ≥ 0	0.085 ( 0.8)	0.183 ( 6.3)	0.021 ( 0.7)	-0.361 (-2.1)	1.462 (13.2)	-0.150 (-0.9)	0.855
ps/obs	0.087 ( 6.7)	0.021 ( 5.8)	-0.001 (-0.4)	-0.035 (-1.4)	0.065 ( 4.5)	-0.049 (-2.3)	
pc > 0	0.359 ( 4.2)	0.071 ( 2.9)	0.046 ( 2.0)	0.024 ( 0.1)	-0.532 (-5.5)	0.402 ( 2.8)	0.707
pc > 1	0.539 ( 6.4)	-0.041 (-1.8)	0.007 ( 0.3)	-0.255 (-1.6)	-1.341 (-14.6)	-0.001 ( 0.0)	0.369

Notes: binary probit models, OLS for ps/obs.

sample: 1981–1992, time and size dummies were included.

cat<sub>1</sub> is share of observations for category 1, pc denotes the number of price changes per year, ps denotes the difference between the number of increases and decreases per year, obs is the number of observations per year.

increases. This is confirmed by the results for the net price increases. This is again consistent with the theoretical model: it implies that the price elasticity of demand is lower in those sectors; a reduction of uncertainty should lead to lower prices. In addition, the effect on the price elasticity outweighs the effect from lower demand due to better products of competitors.

A high sector share of process innovators (proc<sup>s</sup>) tends to reduce prices. The estimates reveal that the probability of a price decrease is increased, the effect on the probability of a price increase is not clear. The effects are stronger for the second half of the year. These effects are more pronounced for each month and are not significant for most of the annual specifications. The estimates also show that the volatility of prices is higher. These results indicate a stronger price competition in those sectors. Process innovations of other firms increase competitive pressure, i.e. competition is harder, if other firms can produce at lower costs. Finally, the coefficients of the size dummies show that small firms ( $\bar{l} < 50$ ) less often report a price increase and more often report a price decrease. The results for large firms ( $\bar{l} > 1000$ ) are mixed; the probability of price decreases is higher than for medium size firms (*ceteris paribus*).

The estimation results for employment are reported in table 11 and table 12. The explanatory variables are the same as for prices. From the theoretical model, a positive effect from capacity utilization on employment is expected. The effect from product innovations is ambiguous, since the demand increasing effect may be counteracted by a negative output effect from less competition. The effects from process innovations and investment are also ambiguous, since the positive scale effect stands against the negative substitution effect. Innovations of other firms should reduce employment.

The empirical estimates reveal clearly the expected positive impact from capacity utilization on employment. A high utilization of capacities increases the probability of employment increases and decreases the probability of employment decreases. The effect is highly significant; the result holds for each of the quarterly employment equations and for each of the annual specifications. In addition, a high capacity utilization reduces the volatility of employment. With insufficient capacities, firms react with price adjustments instead of quantity adjustments.

Product innovations increase the probability of employment increases, but also tend to increase the probability of employment decreases. The effect on employment increases appears to be stronger which is confirmed by the positive effect on net increases. That means, the (positive) demand increasing effect of product innovations seems to outweigh the (negative) price effect. The higher volatility of employment is consistent with the lower volatility of prices; a lower price elasticity of demand favours employment adjustments against price adjustments. An additional explanation could be that the uncertain outcome of product innovations increases the volatility of demand.

Process innovations also increase both the probability of employment increases and decreases. The effect is less pronounced than those of product innovations. It is not significant for employment decreases and positive for net increases, i.e. the positive scale effect of process innovations seems to compensate the negative substitution effect. This interpretation is confirmed by the results for investment. Investment increases the probability of employment increases and reduces the probability of employment decreases. Note also that process innovations increase the volatility of employment. This could mean that for some firms the scale effect exceed the substitution effect of process innovations, while for other firms the ordering is *vive versa*. Investment, on the other hand, tends to reduce the volatility of employment.

Product innovations of other firms in the sector also tend to increase both the probability of employment increases and employment decreases. The employment decreasing effect is stronger, i.e. better products of other firms reduce demand and employment. In addition, the volatility of employment is higher, which is consistent with a lower price elasticity of demand in those sectors which was found also for prices (see above). The estimates do not show significant effects from process innovations of other firms on employment increases or decreases.

**Table 11: Employment increases and decreases**

endogenous variable: employment increase, $l^+$								
quarter	<i>DUC</i>	prod	proc	<i>IY</i>	prod <sup>s</sup>	proc <sup>s</sup>	$\bar{l} < 50$	$\bar{l} > 1000$
Q1	1.618 ( 11.4)	0.251 ( 6.5)	0.080 ( 2.2)	0.609 ( 2.7)	0.242 ( 1.6)	-0.049 (-0.2)	0.056 ( 1.0)	-0.053 (-1.3)
Q2	1.808 ( 12.3)	0.259 ( 6.6)	0.088 ( 2.4)	0.759 ( 3.4)	0.049 ( 0.3)	0.097 ( 0.4)	0.055 ( 0.9)	0.006 ( 0.2)
Q3	1.583 ( 10.6)	0.177 ( 4.4)	0.071 ( 1.9)	0.158 ( 0.6)	0.034 ( 0.2)	0.289 ( 1.3)	0.059 ( 1.0)	0.012 ( 0.3)
Q4	1.654 ( 10.1)	0.219 ( 5.1)	0.034 ( 0.8)	0.390 ( 1.5)	0.238 ( 1.4)	0.072 ( 0.3)	-0.015 (-0.2)	0.034 ( 0.8)
endogenous variable: employment increase at least once a year, $l1^+$								
	0.971 ( 8.9)	0.256 ( 8.9)	0.073 ( 2.6)	0.560 ( 3.1)	0.077 ( 0.7)	0.196 ( 1.2)	0.008 ( 0.2)	-0.032 (-1.0)
endogenous variable: employment increase more than once a year								
	1.211 ( 7.7)	0.300 ( 7.5)	0.113 ( 3.0)	0.573 ( 2.4)	0.376 ( 2.4)	-0.041 (-0.2)	-0.013 (-0.2)	0.017 ( 0.4)
endogenous variable: employment decrease, $l^-$								
Q1	-1.792 (-20.0)	0.025 ( 0.8)	0.001 ( 0.0)	-0.494 (-2.2)	0.316 ( 2.6)	0.287 ( 1.6)	-0.372 (-7.7)	0.204 ( 6.4)
Q2	-2.118 (-22.1)	0.037 ( 1.2)	0.052 ( 1.7)	-1.105 (-3.8)	0.686 ( 5.4)	-0.262 (-1.4)	-0.493 (-9.3)	0.166 ( 5.1)
Q3	-2.239 (-23.2)	0.083 ( 2.6)	0.034 ( 1.1)	-0.495 (-1.9)	0.534 ( 4.2)	0.025 ( 0.1)	-0.418 (-8.0)	0.086 ( 2.6)
Q4	-2.265 (-23.7)	0.108 ( 3.4)	0.036 ( 1.2)	-0.401 (-1.6)	0.403 ( 3.2)	0.187 ( 1.0)	-0.378 (-7.6)	0.144 ( 4.4)
endogenous variable: employment decrease at least once a year, $l1^-$								
	-1.568 (-17.7)	0.051 ( 2.0)	0.016 ( 0.7)	-0.376 (-2.1)	0.554 ( 5.6)	0.034 ( 0.2)	-0.316 (-8.5)	0.094 ( 3.5)
endogenous variable: employment decrease more than once a year								
	-1.608 (-15.5)	0.050 ( 1.7)	0.027 ( 0.8)	-0.982 (-3.8)	0.535 ( 4.6)	0.232 ( 1.4)	-0.480 (-9.7)	0.186 ( 6.0)

Notes: binary probit models,  
sample: 1981-1992, time dummies (1981-1991) were included

**Table 12: Employment changes**

	<i>DUC</i>	prod	proc	<i>IY</i>	prod <sup>s</sup>	proc <sup>s</sup>	cat <sub>1</sub>
ls > 0	1.131 ( 9.9)	0.260 ( 8.7)	0.064 ( 2.2)	0.660 ( 3.6)	0.133 ( 1.1)	0.134 ( 0.8)	0.145
ls ≥ 0	1.595 ( 17.8)	-0.039 (-1.6)	-0.001 (-0.1)	0.346 ( 1.9)	-0.583 ( -5.8)	-0.002 ( 0.0)	0.720
ls/obs	0.403 ( 19.8)	0.018 ( 3.2)	0.006 ( 1.1)	0.166 ( 4.3)	-0.080 ( -3.6)	0.003 ( 0.1)	
lc > 0	-0.775 ( -9.3)	0.177 ( 7.6)	0.047 ( 2.1)	0.068 ( 0.4)	0.490 ( 5.4)	0.150 ( 1.1)	0.436
lc > 1	-0.830 ( -8.9)	0.151 ( 5.8)	0.071 ( 2.8)	-0.461 (-2.3)	0.488 ( 4.7)	0.214 ( 1.4)	0.217

Notes: binary probit models, OLS for ls/obs.

sample: 1981–1992, time and size dummies were included.

cat<sub>1</sub> is the share of observations for category 1, lc denotes the number of employment changes per year, ls denotes the difference between the number of increases and decreases per year, obs is the number of observations per year.

The estimates also show that the probability of employment decreases is lower for small firms and higher for large firms, as compared with medium size firms. They do not reveal a significant effect from firm size on the probability of employment increases. Finally, all equations were tested for a bias due to endogenous attrition. For this purpose, all versions are estimated either

- with a dummy which is equal to one for those firms that leave the business survey during the observation period (leaver), or
- with two dummies, which are equal to one in one of the two periods before the firm leaves the business survey ( $exit_t$ ,  $exit_{t+1}$ )

The results for selected equations are reported in [table 28](#) in the appendix. For comparison, the first version for each variable is the corresponding model equation without attrition.<sup>67</sup> The price equations reveal that firms which leave the panel increase their prices significantly less often. The dummies are not significant in the equation for price decreases. The employment equations reveal that firms which left the panel increased employment less often and

<sup>67</sup>Note that for many firms that left the panel in period  $t$ , missing values for some of the variables are encountered, and  $exit_t$  is not defined for the year 1992. Therefore the sample is smaller.

decreases employment more often. These effects are highly significant which supports the hypothesis that leaving the panel indicates bad business prospects of the firm, in addition to a low capacity utilization. Most important, all coefficients and  $t$ -values of the model variables remain nearly unchanged, only the effect from utilization on prices and employment is slightly lower, if it is controlled for attrition. This is expected, since a high utilization of capacities reduces the probability of exit (see above). These results for attrition are comfortable, i.e. they do not destroy the confidence into the estimates of the economic model.

### 3.4.2 Output and capacity utilization

Now, the results for output and capacity utilization are reported. For net output changes and the volatility of output, the results are reported in [table 13](#). For the monthly output increases and output decreases, a reduced form model is specified, i.e. the capacity utilization rate is excluded from the list of explanatory variables. The results are reported in [table 26](#) and [table 27](#) in the appendix.

First, a high capacity utilization strongly reduces the volatility of output changes and increases the probability of positive net increases. The first effects supports again the assumption that capacities can be binding in the short run. Quantity adjustments are restricted, the firms more often adjust prices. The positive effect of capacity utilization on net output (and price and employment) increases confirms the assumption of positive autocorrelation of demand shocks.

Second, product innovations strongly increase the probability of net output increases, i.e. product innovating firms produce more. This result confirms that the effect of product innovations on the level of demand exceeds the output decreasing effect of price increases due to a lower price elasticity of demand. In addition, product innovations increase the volatility of output. This confirms that product innovations reduce the price elasticity of demand and/or increase the variance of demand shocks. Price changes are less frequent and output and employment changes are more frequent.

Process innovations and investment also increase the probability of net output increases which is expected from the theoretical model. Note that these positive effects of process innovations and investment on output and employment supports the relevance of price effects. The effect of process innovations appears to be stronger, but it should be hold in mind that process innovations (and output changes) refer to the product level, while investment refers to the firm level.

A large share of product innovators in the sector significantly reduces the probability of output increases and output decreases, i.e. it reduces the volatility of output. This confirms again that a market which is characterized by a large share of product innovators implies less uncertainty for the firm. Each firm produces specific products and is protected from the behaviour of other firms. The variability of both prices and output is reduced, product inno-

**Table 13: Output changes**

	<i>DUC</i>	prod	proc	<i>IY</i>	prod <sup>s</sup>	proc <sup>s</sup>	cat <sub>1</sub>
ys > 0	0.565 ( 6.4)	0.154 ( 6.4)	0.106 ( 4.5)	0.481 ( 3.0)	-0.259 ( -2.7)	0.194 ( 1.4)	0.328
ys ≥ 0	1.251 ( 14.8)	0.074 ( 3.1)	0.062 ( 2.7)	0.454 ( 2.8)	0.134 ( 1.4)	-0.078 (-0.6)	0.593
ys/obs	0.255 ( 16.1)	0.027 ( 6.1)	0.020 ( 4.6)	0.075 ( 2.5)	-0.030 ( -1.7)	0.002 ( 0.1)	
yc > 0	-1.446 (-16.3)	0.058 ( 2.4)	0.081 ( 3.4)	0.278 ( 1.6)	-0.866 ( -9.0)	0.469 ( 3.4)	0.688
yc/obs > .5	-1.246 (-13.7)	0.052 ( 2.0)	0.058 ( 2.3)	-0.026 (-0.1)	-0.689 ( -6.8)	0.237 ( 1.6)	0.204

Notes: binary probit models, OLS for ys/obs.

sample: 1981–1992, time and size dummies were included.

cat<sub>1</sub> is the share of observations for category 1, yc denotes the number of output changes per year, ys denotes the difference between the number of increases and decreases per year, obs is the number of observations per year.

vations affect the market structure. The net effect of the share of product innovators on output (and employment) seems to be negative. Better products of competitors reduce demand.

Process innovations of other firms in the sector tend to increase the frequency of output changes. Although the effect is not clear for each month, it is clearly visible in the annual specifications. This supports the hypothesis that competition is strong in those sectors. Demand changes very often, and output (and price) adjustments are frequent. The effect of sectoral process innovations on net output increases is inconclusive.<sup>68</sup>

The results for the firm size dummies reveal that the probability of output increases is lower and the probability of output decreases is higher for small firms. For large firms, the probability of output changes is lower, i.e. the variability of output is lower than in the reference group. This can be caused by a lower variance of demand shocks for those firms, but it may also be an endogenous reaction of large firms: large firms, on average, exhibit a higher capital intensity; therefore, they have more incentives to utilize their capacities and change output less often.

The results for capacity utilization are reported in [table 14](#). They reveal

<sup>68</sup>One can only speculate whether the estimated output increase in the second half of the year resulted from price decreases.

**Table 14: Capacity utilization**

endogenous variable: capacity utilization, <i>DUC</i>							
quarter	prod	proc	<i>IY</i>	prod <sup>s</sup>	proc <sup>s</sup>	$\bar{l} < 50$	$\bar{l} > 1000$
Q1	0.019 (6.2)	0.022 (7.6)	0.092 (4.4)	0.021 (1.8)	-0.038 (-2.2)	-0.058 (-13.8)	0.024 (7.2)
Q2	0.016 (5.2)	0.020 (6.6)	0.091 (4.4)	0.033 (2.8)	-0.106 (-6.0)	-0.059 (-13.7)	0.025 (7.6)
Q3	0.017 (5.4)	0.020 (6.7)	0.119 (5.7)	0.049 (0.4)	-0.086 (-4.8)	-0.065 (-16.2)	0.024 (7.3)
Q4	0.016 (5.1)	0.025 (8.2)	0.039 (1.8)	0.040 (3.3)	-0.088 (-4.8)	-0.066 (-14.9)	0.027 (8.0)
year	0.014 (5.9)	0.022 (9.1)	0.075 (4.5)	0.014 (1.4)	-0.057 (-4.0)	-0.059 (-17.5)	0.023 (8.5)

Notes: tobit model,  
sample: 1981-1992, time dummies (1981-1991) were included

that both product and process innovation exhibit a positive and highly significant impact. The quantitative impact is non-negligible: each, product innovations and process innovations increase utilization by about 2 percent. Innovative firms are more successful! This is probably mostly due to the demand increasing effect of innovations. Investment also exhibits a positive impact on capacity utilization. This result is more surprising, since investment also increases capacities and reduces the probability of supply constraints. However, the demand increasing effect of investment due to lower costs and prices seems to exceed the capacity effect. Another reason can be that firms which produce with a more capital-intensive production technology have more incentives to achieve a higher utilization.

A large share of product innovators in the sector has a positive impact on utilization. This is consistent with the reduction of the volatility of output. Each firm produces a specific product and is protected from the behaviour of other firms. Firms must change prices and output less often and can achieve a higher utilization. This effect outweighs the demand reduction of better products of competitors. Process innovations of other firms, on the other hand, have a clear negative effect on capacity utilization. They reduce demand and prices, and increase the volatility of output. Therefore, it is more difficult for the firm to achieve a high utilization.

Finally, the firm size has a clear and highly significant positive effect on utilization. This is again consistent with a lower demand uncertainty and a higher capital intensity of large firms. Note that these results for capacity utilization



imply that innovation, investment, and firm size exhibit an additional effect on prices and employment. Those variables significantly affect capacity utilization, and capacity utilization, in turn, significantly affects the probability of price and employment changes.<sup>69</sup>

### 3.4.3 The quantitative impact on employment and sales

In table 15, the estimation results for the quantitative data for employment and sales from the investment survey are reported. Note that these data and the data on investment refer to the whole firm, while the other data refer to a specific product.<sup>70</sup> The regression results are reported both for the structural model and for a reduced form without capacity utilization.

First, again a highly significant positive effect from capacity utilization on employment and sales is found. This confirms the assumptions about the time structure of the adjustments and the autocorrelation of demand shocks. The results with the quantitative data also confirm that product innovations increase both employment and sales. Surprisingly, the estimated effect on employment exceeds that on sales. From the theoretical model, a different ordering is expected (product innovations increase quantities and prices), but the difference is small and not significant.<sup>71</sup> The effect from product innovations is larger in the reduced form model which could be expected, since product innovations also increase utilization. The total (medium-run) quantitative effect of product innovations on employment is slightly below 1 percent.

The effect of process innovations on employment is not significant in the structural model, but becomes significantly positive in the reduced form. That means, process innovations increase employment mainly through their effect on capacity utilization. The effect from process innovations on sales is not significant, i.e. the positive output effect is partly compensated by a negative price effect.<sup>72</sup> Investment increases both employment and sales. In this case, the ordering of the effects is correct. The coefficient in the sales equation exceeds that in the equation for employment.

The effect from product innovations of competitors on employment is negative which corresponds to the results achieved with the qualitative data above. The respective effect for sales is not significant. This is again evidence that

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<sup>69</sup>The results are also robust with respect to the introduction of the attrition dummies. Leavers exhibit a lower probability of output increases, a higher probability of output decreases, and a lower utilization of capital (not reported). Again, the other coefficients remain nearly unchanged.

<sup>70</sup>In most cases, the product corresponds to the whole firm. These equations were also estimated for the subsample of firms, where the product level corresponds to the firm level. The results are nearly the same as those reported.

<sup>71</sup>In addition, it should be noted that the endogenous variable is sales and not value added. The data are not corrected for material input (costs) which can bias the coefficients downwards.

<sup>72</sup>In addition, process innovations are related to investment. Therefore, investment at the firm level may be a better indicator for process innovations at the firm level than process innovations at the product level.

**Table 15: Employment and sales**

endogenous variable: employment changes, $\Delta \ln l$							
<i>DUC</i>	prod	proc	<i>IY</i>	prod <sup>s</sup>	proc <sup>s</sup>	$\bar{l} < 50$	$\bar{l} > 1000$
0.090	0.007	0.002	0.133	-0.029	0.029	-0.002	-0.005
(13.9)	(4.1)	(1.0)	(10.5)	(-4.2)	(2.8)	(-0.9)	(-2.4)
	0.009	0.004	0.138	-0.029	0.026	-0.006	-0.003
	(4.8)	(2.2)	(11.0)	(-4.2)	(2.5)	(-2.5)	(-1.5)
endogenous variable: sales changes, $\Delta \ln s$							
0.067	0.006	0.001	0.190	0.011	-0.016	-0.014	0.003
(7.3)	(2.3)	(0.3)	(10.7)	(1.1)	(-1.1)	(-3.8)	(1.1)
	0.007	0.002	0.195	0.011	-0.020	-0.017	0.004
	(2.8)	(0.9)	(11.1)	(1.1)	(-1.4)	(-4.7)	(1.6)

Notes: OLS estimates,

sample: 1981-1992, time dummies (1981-1991) were included

prices, on average, increase, if the sector is characterized by a higher share of product innovators. The share of process innovators shows up with an inconsistent positive sign in the employment equation. At this stage, one can only speculate to what extent this effect is only a spurious correlation, or to what extent it is meaningful, i.e. results from demand increases due to price decreases. The respective coefficient is negative (as expected), albeit not significant in the equation for sales.

Finally, small firms exhibit a lower growth of employment and sales, but the results do not indicate that large firms grow faster, which would imply a tendency towards monopolization. Again, all equations are tested for a bias due to endogenous attrition. Panel leavers exhibited significantly lower sales and employment changes, the other coefficients remain mostly unchanged. Note that the quantitative effect is quite large (about 2 percent). See table 28 in the appendix.

### 3.5 Summary of estimation results

The results of the empirical estimations are summarized in [table 16](#). The estimated effects can be compared with the theoretically expected effects in [table 2](#) on page 18.

First, a high capacity utilization increases future output, employment and prices. This confirms the assumptions of a positive autocorrelation of demand shocks and a delayed adjustment of prices and employment. A high capacity utilization also increases the volatility of prices and reduces the volatility

of output and employment. This is evidence for the importance of capacity constraints in the short and medium run.

Second, product innovations increase future output, prices, employment and capacity utilization. This indicates both an increase of the level of demand and a reduction of the price elasticity of demand. Product innovations also increase the volatility of output and employment and tend to reduce the volatility of employment. This confirms the hypothesis that product innovations reduce the price elasticity of demand: a lower price elasticity of demand favours quantity adjustments against price adjustments. Process innovations increase future output, employment, and capacity utilization, i.e. innovative firms are more successful. Surprisingly, the estimates do not reveal a conclusive effect from process innovations on prices. However, it is difficult to see how process innovations can increase output and employment if not via lower prices. Process innovations also increase the volatility of output and employment. The results for investment are similar. Investment increases future output, employment, and capacity utilization, the price effect is only weakly significant.

A large share of product innovators in the sector reduces the volatility of output and prices, increases the volatility of employment, and increases capacity utilization. This confirms that product innovations affect the market structure: first, the price elasticity of demand is lower in those sectors, and employment adjustment is favoured against price adjustments; second, the variance of demand shocks is lower. Output changes are less frequent and the firms can achieve a higher capacity utilization. Each firm produces a specific product, and demand is protected from the behaviour of competitors. This interpretation is confirmed by the negative effect of sectoral product innovations on net output and employment increases and the positive effect on net price increases. Process innovations of competitors increase the volatility of output and prices and reduce capacity utilization. This indicates that in those sectors the price elasticity of demand is higher and/or the variance of demand shocks is higher. The negative effect on sales indicates stronger competition, the effect on employment is inconclusive.

Finally, attrition was treated as an endogenous variable. The probability of leaving the panel is lower in case of a high utilization of capacities and lower for innovators. This supports the hypothesis that leaving the panel is correlated with leaving the market. Attrition is endogenous, and the estimates were tested against a sample selection bias. Introducing dummies for attrition revealed that firms which leave the panel during the observation period, on average, exhibit lower prices, employment, sales, and a lower capacity utilization. Nevertheless, the coefficients of the model variables remained nearly unchanged: attrition is endogenous, but the sample selection bias is low.

**Table 16: Estimated effects of innovation**

	<i>DUC</i>	prod	proc	<i>IY</i>	prod <sup>s</sup>	proc <sup>s</sup>	$\bar{l} < 50$	$\bar{l} > 1000$	exit
$p^+$	++	+	?	?	--	?	-	?	-
$p^-$	--	--	?	?	--	+	+	+	?
ps	++	++	?	-	++	?	-	-	-
pc	++	?	?	?	--	+	?	?	-
$l^+$	++	++	+	+	?	?	?	?	-
$l^-$	--	+	?	-	+	?	-	+	+
ls	++	++	+	+	-	?	+	-	-
lc	--	++	+	-	++	?	-	+	+
$\Delta \ln l$	++	++	+	++	-	+	-	-	-
$y^+$		++	++	+	--	+	-	-	-
$y^-$		-	-	-	-	+	+	-	+
ys	++	++	++	+	-	?	-	?	-
yc	--	+	+	?	--	+	-	-	?
$\Delta \ln s$	++	+	?	++	?	-	-	?	-
<i>DUC</i>		++	++	++	+	--	-	+	-
exit	--	-	-	?	+	+	?	-	

- + (++) denotes a (highly) significant positive effect,
- (--) denotes a (highly) significant negative effect,
- ? denotes an inconclusive or insignificant effect.

## 4 Conclusion

In this paper, a theoretical model of the impact of innovations on output, capacity utilization, employment and prices is developed. For the model, a delayed adjustment of prices and employment is assumed to disentangle short-run demand-induced adjustments. It is assumed that product innovations affect demand, and process innovations reduce production costs. In addition, it is allowed for effects of own and other firms' innovations on the market structure. The model is estimated with micro-data of West German manufacturing firms.

The results revealed that the capacity utilization rate exhibits the theoretically expected positive influence on prices and employment. The effect is highly significant and indicates that it is important to control for short-run business cycle induced changes when analyzing medium- and long-run effects. The estimates become more efficient. The assumption of a delayed adjustment appears as a useful analyzing tool to allow for these effects.

Second, firms which implemented product innovations increase prices, exhibit a higher utilization, and more output and employment growth. The demand increasing effect of product innovations exceeds the negative effect from higher prices. Process innovations also exhibit a positive impact on output and capacity utilization. The employment effect is also positive, i.e. the scale effect exceeds the substitution effect. A conclusive effect from process innovations on prices is not revealed by the estimates. Product and process innovations increase the volatility of output and employment.

The positive effects of innovations raise the question why then do not all firms innovate, or which firms innovate. The reasons can be that innovative firms can build on historically accumulated knowledge and exhibit an advantage on the learning curve. In addition, the market structure and financial constraints offer different incentives and opportunities for different firms. The analysis of the determinants of innovation is contained in a subsequent paper (Smolny (1996)). Further work is in progress to estimate the impact of innovations on productivity growth and to test for spillovers of innovative activities.

Finally, innovations significantly affect the market structure. Product innovations reduce the price elasticity of demand, and in sectors with a large share of product innovators, the price elasticity is lower. In those sectors, the volatility of prices is lower, and the volatility of employment is higher. The lower frequency of output changes and the higher capacity utilization indicate less demand uncertainty in those sectors. Each firm produces specific products and is protected from the behaviour of competitors. Process innovations of other firms in the sector, on the other hand, reduce prices, increase the volatility of output, employment, and prices, and reduce the utilization of capacities. This indicates a more competitive market structure in those sectors. It remains to be analyzed to what extent these changes of the market structure, in turn, affect innovation behaviour.

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## Appendix

Table 17: List of variables

variable	freq
prod:	(a) dummy variable, 1 for product innovation
proc:	(a) dummy variable, 1 for product innovation
prod <sup>s</sup> :	(a) share of product innovators in the sector
proc <sup>s</sup> :	(a) share of process innovators in the sector
$p^+$ :	(m) dummy variable, 1 for price increase
$\bar{p}^+$ :	(a) relative number of price increases
$p1^+$ :	(a) dummy variable, 1 for price increase at least once a year
ps:	(a) net price increases
pc:	(a) number of price changes
$l^+$ :	(q) dummy variable, 1 for employment increase
$\bar{l}^+$ :	(a) relative number of employment increases
$l1^+$ :	(a) dummy variable, 1 for employment increase at least once a year
ls:	(a) net employment increases
lc:	(a) number of employment changes
$y^+$ :	(m) dummy variable, 1 for output increase
$\bar{y}^+$ :	(a) relative number of output increases
$y1^+$ :	(a) dummy variable, 1 for output increase at least once a year
ys:	(a) net output increases
yc:	(a) number of output changes
$DUC$ :	(q) capacity utilization, $0.3 \leq DUC \leq 1.0$
$\Delta \ln l$ :	(a) rate of change of employment
$\Delta \ln s$ :	(a) rate of change of sales
$IY$ :	(a) share of investment in sales
exit:	(a) dummy variable, 1 for exit in the next period
leaver:	(a) dummy variable, 1 for leavers of the panel
$\bar{l} < 50$ :	(a) dummy variable, 1 for firms with less than 50 employees
$\bar{l} > 1000$ :	(a) dummy variable, 1 for firms with more than 1000 employees

(a): annual data, (q): quarterly data, (m): monthly data.

Decreases  $-$  are defined correspondingly.  $l$  are planned employment changes,  $p, y$  are realized changes. These figures refer to the product.  $\Delta \ln l, \Delta \ln s, IY$  are realized figures at the firm level. exit and leaver refer to the business survey.

**Table 18: Manufacturing sectors**

ifo	Sypro	sector	sample	total
21	25	stone, clay	0.042	0.079
22	27/30	drawing, cold-rolling mills	0.012	0.010
23	28/29	foundry	0.016	0.016
24	22	mineral oil	0.004	0.002
25	24/40	chemicals	0.015	0.035
26	53	wood	0.037	0.043
27	55	paper	0.018	0.004
28	59	rubber	0.007	0.006
31	31	steel products	0.030	0.034
32	32/50	machinery	0.141	0.125
33	33/34/35	car manufacturing	0.034	0.062
34	36	electrical products	0.052	0.077
35	37	precision and optical goods	0.033	0.031
37	30	steel	0.041	0.033
38	38	ironware	0.050	0.054
411	51	fine ceramics	0.012	0.004
412	52	glass	0.023	0.008
42	54	furniture	0.053	0.052
43	39	musical instruments, toys, etc.	0.014	0.015
441	56	paper products	0.044	0.019
442	57	printing	0.090	0.044
45	58	plastic	0.038	0.047
46	61/62	leather	0.022	0.014
471	63	textiles	0.060	0.038
472	64	clothing	0.026	0.053
51	68/69	food, beverages	0.083	0.098
52	68/69	tobacco	0.005	0.001

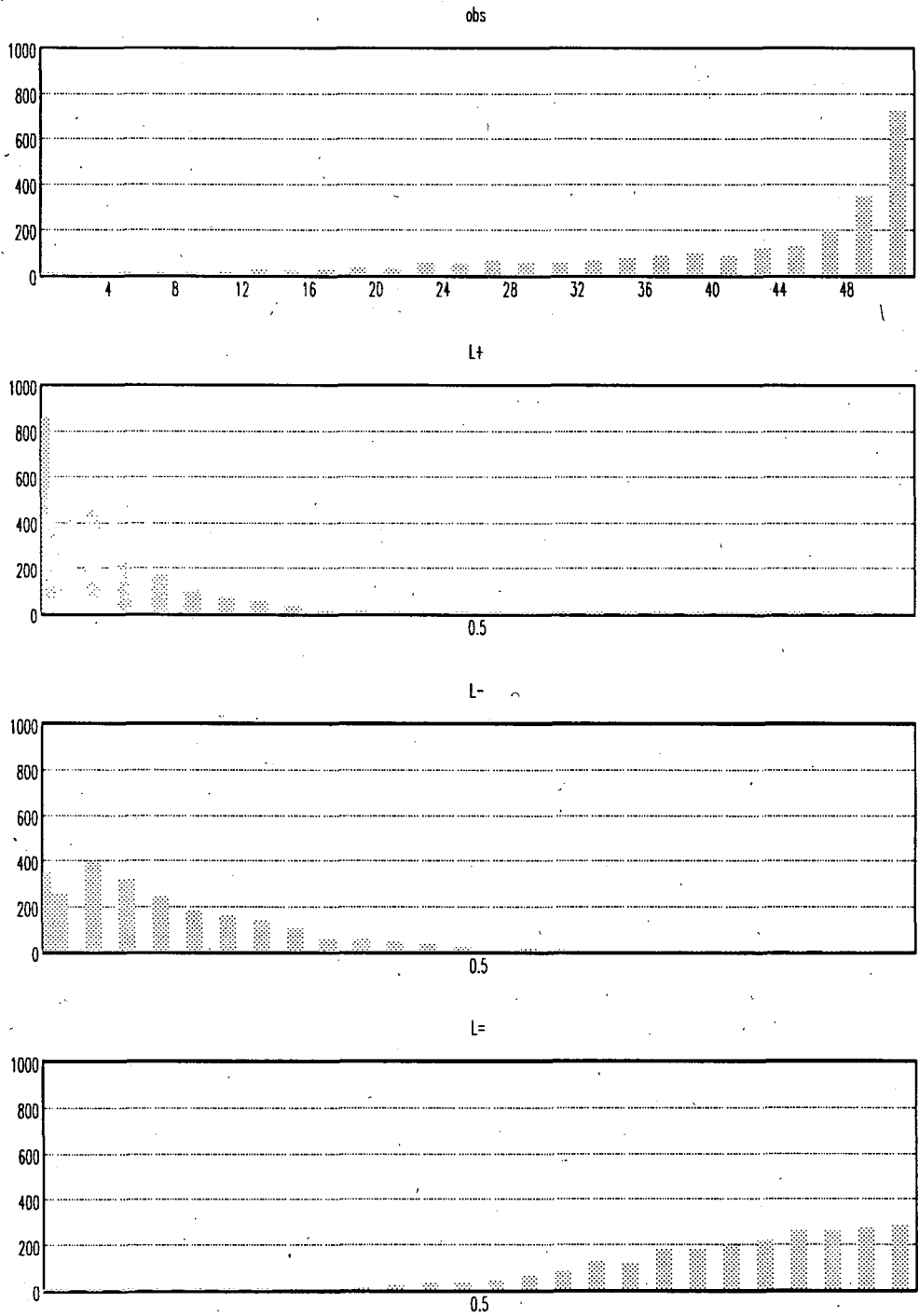
Notes: *ifo* is the sector classification of the ifo institute,  
*Sypro* is the classification according to the German Statistical Office.  
*Sample* denotes the share of firms in the ifo firm panel,  
*total* denotes the shares in total manufacturing.

Table 19: Innovation, investment, employment, and sales

sector	firms	$\bar{l} < 50$	$\bar{l} > 1000$	$\bar{l}$	prod	proc	$\Delta Y$	$\Delta \ln l$	$\Delta \ln s$
21	95	25	3	250	0.330	0.358	0.101	-0.008	0.033
22	26	3	3	383	0.405	0.409	0.054	-0.015	0.019
23	40	2	16	1329	0.368	0.465	0.041	-0.003	0.019
24	8	0	5	2295	0.379	0.466	0.015	-0.036	-0.023
25	35	11	7	6860	0.450	0.413	0.054	-0.026	0.001
26	86	39	4	353	0.206	0.300	0.059	-0.006	0.014
27	55	4	16	1286	0.324	0.427	0.087	0.008	0.044
28	19	1	11	2716	0.677	0.496	0.044	-0.029	0.038
31	79	1	30	1815	0.404	0.356	0.028	-0.024	0.030
32	310	19	107	1606	0.647	0.510	0.041	-0.007	0.041
33	81	4	48	10016	0.670	0.572	0.048	-0.014	0.044
34	171	5	90	4568	0.684	0.625	0.053	-0.005	0.045
35	79	19	14	667	0.612	0.447	0.044	-0.008	0.036
37	91	13	13	461	0.408	0.487	0.049	0.000	0.032
38	115	24	8	403	0.494	0.487	0.040	-0.010	0.029
411	29	0	10	1563	0.670	0.628	0.057	-0.010	0.030
412	64	7	13	747	0.578	0.509	0.062	-0.014	0.026
42	112	20	5	269	0.590	0.447	0.038	-0.003	0.035
43	27	4	2	365	0.570	0.480	0.046	-0.021	0.038
441	116	23	11	401	0.342	0.383	0.060	-0.002	0.040
442	185	42	5	198	0.238	0.409	0.074	0.003	0.049
45	98	16	6	285	0.472	0.440	0.059	-0.003	0.033
46	55	3	5	357	0.490	0.378	0.020	-0.052	0.005
471	162	8	31	632	0.583	0.492	0.038	-0.027	0.019
472	53	9	5	365	0.495	0.392	0.022	-0.042	0.013
51	174	36	10	445	0.416	0.365	0.053	-0.004	0.038
52	10	3	4	950	0.511	0.522	0.027	-0.005	0.037
total	2405	341	482	1408	0.497	0.459	0.051	-0.009	0.034

Source: ifo firm panel. The sector definitions are contained in table 18.

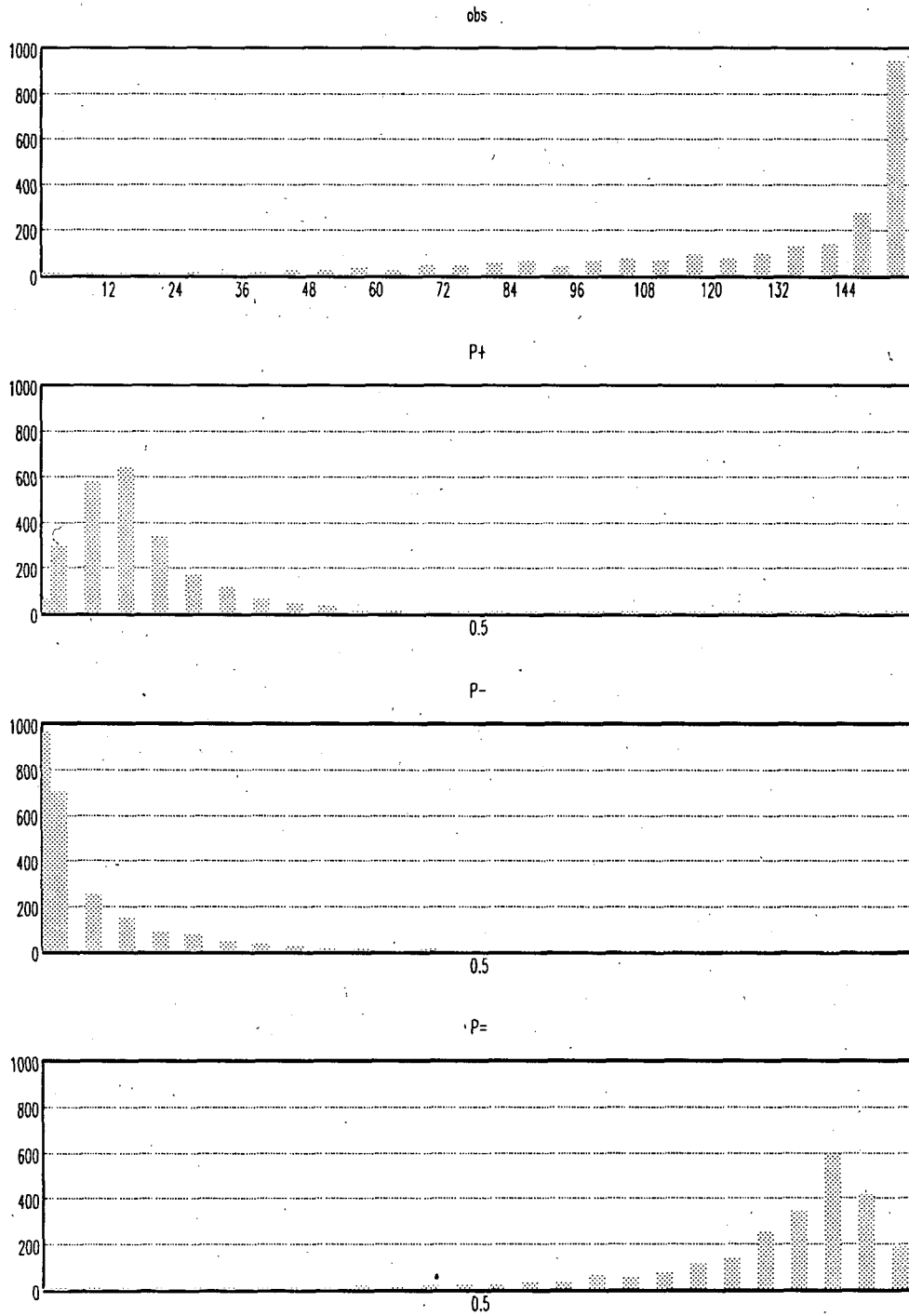
Figure 6: Frequency of employment changes



Source: ifo firm panel, 2405 firms, 13 x 4 quarters

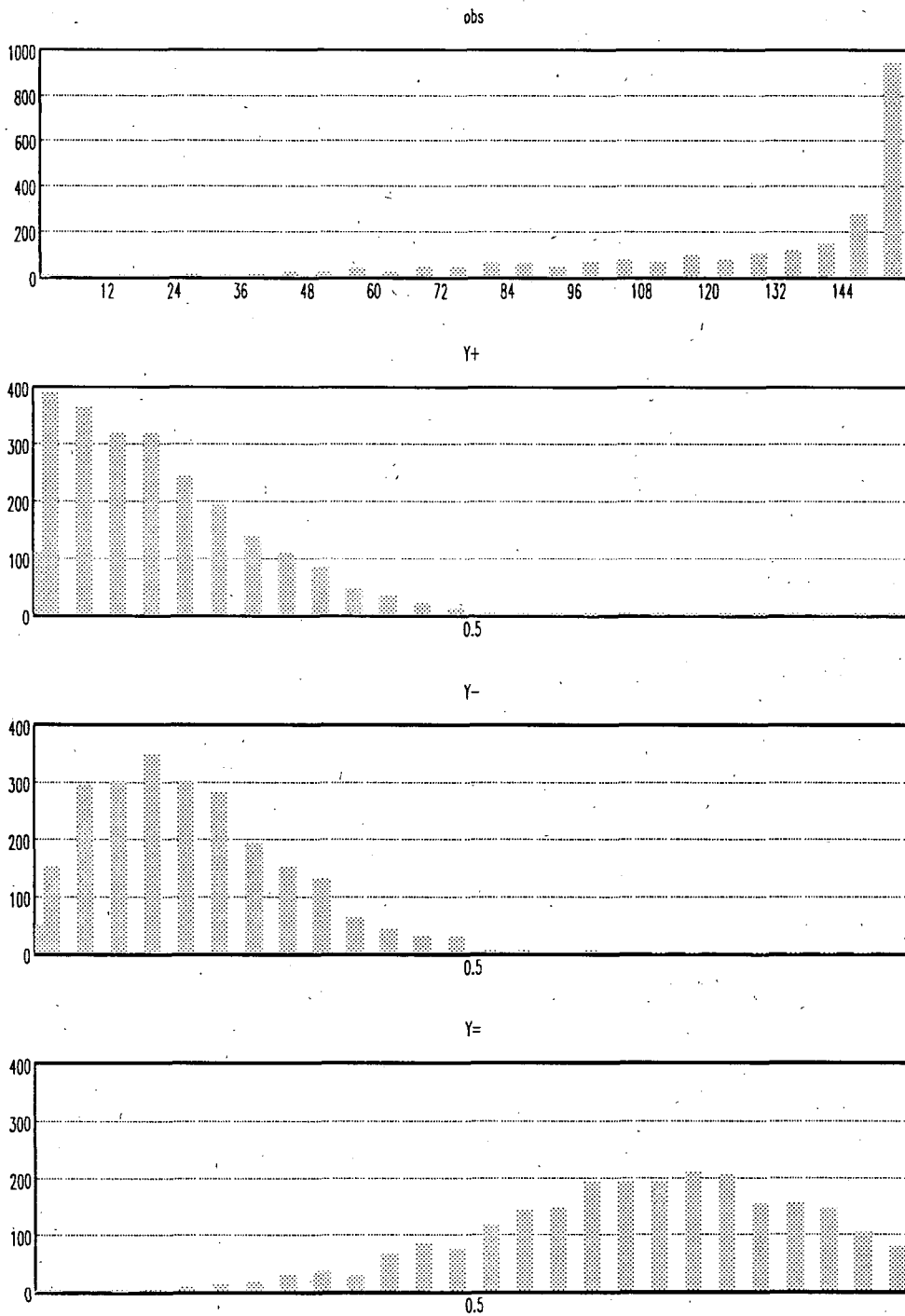
The first bar denotes 0, the class width is 2 (2/52).

Figure 7: Frequency of price changes



Source: ifo firm panel, 2405 firms, 13 x 12 months  
 The first bar denotes 0, the class width is 6 (6/156).

Figure 8: Frequency of output changes



Source: ifo firm panel, 2405 firms, 13 x 12 months  
 The first bar denotes 0, the class width is 6 (6/156).



Table 20: Prices, employment, output, and capacity utilization

sector	$p^+$	$p^-$	$l^+$	$l^-$	$y^+$	$y^-$	$DUC$	exits	firms
21	0.081	0.068	0.034	0.116	0.134	0.209	0.782	16	95
22	0.147	0.035	0.113	0.138	0.199	0.202	0.801	6	26
23	0.180	0.167	0.037	0.124	0.114	0.177	0.852	7	40
24	0.286	0.283	0.044	0.235	0.095	0.128	0.807	2	8
25	0.099	0.068	0.022	0.090	0.128	0.177	0.789	15	35
26	0.133	0.138	0.035	0.090	0.082	0.181	0.818	17	86
27	0.170	0.117	0.028	0.062	0.106	0.142	0.919	3	55
28	0.086	0.088	0.068	0.161	0.066	0.115	0.868	8	19
31	0.080	0.066	0.079	0.134	0.109	0.161	0.818	34	79
32	0.087	0.018	0.093	0.160	0.116	0.156	0.842	35	340
33	0.102	0.023	0.079	0.215	0.141	0.155	0.801	29	81
34	0.097	0.022	0.097	0.165	0.146	0.154	0.836	20	171
35	0.100	0.012	0.071	0.166	0.121	0.168	0.807	20	79
37	0.143	0.052	0.077	0.134	0.150	0.188	0.825	26	91
38	0.094	0.017	0.065	0.120	0.145	0.173	0.811	15	115
411	0.115	0.019	0.037	0.217	0.102	0.159	0.870	8	29
412	0.106	0.024	0.055	0.166	0.129	0.189	0.846	22	64
42	0.101	0.025	0.089	0.121	0.163	0.172	0.837	18	112
43	0.125	0.028	0.061	0.165	0.122	0.153	0.817	12	27
441	0.213	0.076	0.087	0.094	0.176	0.181	0.833	28	116
442	0.096	0.061	0.080	0.096	0.189	0.209	0.821	37	185
45	0.134	0.068	0.063	0.122	0.152	0.210	0.776	12	98
46	0.104	0.029	0.024	0.152	0.093	0.154	0.882	21	55
471	0.099	0.049	0.033	0.158	0.116	0.175	0.853	50	162
472	0.087	0.021	0.036	0.154	0.099	0.159	0.874	14	53
51	0.115	0.064	0.049	0.127	0.198	0.202	0.807	58	174
52	0.069	0.023	0.067	0.125	0.309	0.252	0.779	5	10
total	0.111	0.049	0.067	0.137	0.140	0.176	0.829	538	2405

Source: ifo firm panel. The sector definitions are contained in table 18.  
The figures are based on annual averages of monthly or quarterly data.

**Table 21: Distribution over the year**

	$p^+$	$p^-$	obs	$y^+$	$y^-$	obs	$l^+$	$l^-$	obs	$DUC$	$\sigma$	obs
jan	0.192	0.048	25862	0.154	0.191	25877	0.072	0.136	25408			
feb	0.155	0.045	25997	0.152	0.143	26010						
mar	0.150	0.043	25963	0.181	0.115	25974				0.833	0.141	24857
apr	0.161	0.043	25924	0.136	0.155	25934	0.072	0.124	25515			
may	0.126	0.043	25365	0.125	0.165	25370						
jun	0.096	0.045	25644	0.127	0.163	25653				0.833	0.141	24543
jul	0.086	0.044	25498	0.116	0.188	25499	0.065	0.134	25039			
aug	0.070	0.043	25809	0.110	0.215	25816						
sep	0.072	0.053	25776	0.176	0.153	25779				0.831	0.142	24670
oct	0.077	0.060	25837	0.151	0.172	25845	0.056	0.153	25209			
nov	0.064	0.058	25753	0.124	0.189	25754						
dec	0.070	0.052	25609	0.103	0.234	25610				0.822	0.148	24530
total	0.110	0.048	309037	0.138	0.174	309121	0.066	0.137	101171	0.830	0.143	98600

Source: ifo firm panel

**Table 22: Sectoral output, employment, prices, and investment**

year	$\Delta \ln l^s$	$IY^s$	$\Delta \ln y^s$	$\Delta \ln p^s$	$\Delta \ln s^s$
1980		0.048			
1981	-0.021	0.044	-0.023	0.026	0.018
1982	-0.036	0.039	-0.035	0.045	0.008
1983	-0.039	0.042	0.009	0.027	0.024
1984	-0.005	0.041	0.033	0.008	0.064
1985	0.007	0.044	0.028	0.023	0.052
1986	0.010	0.047	0.011	0.063	0.030
1987	-0.001	0.049	0.004	0.024	0.013
1988	-0.002	0.051	0.028	0.008	0.056
1989	0.017	0.054	0.030	0.011	0.072
1990	0.027	0.057	0.055	0.039	0.080
1991	0.015	0.057	0.042	0.025	0.068
1992	-0.016	0.053	-0.023	0.030	0.005
total	-0.004	0.048	-0.013	0.027	0.041

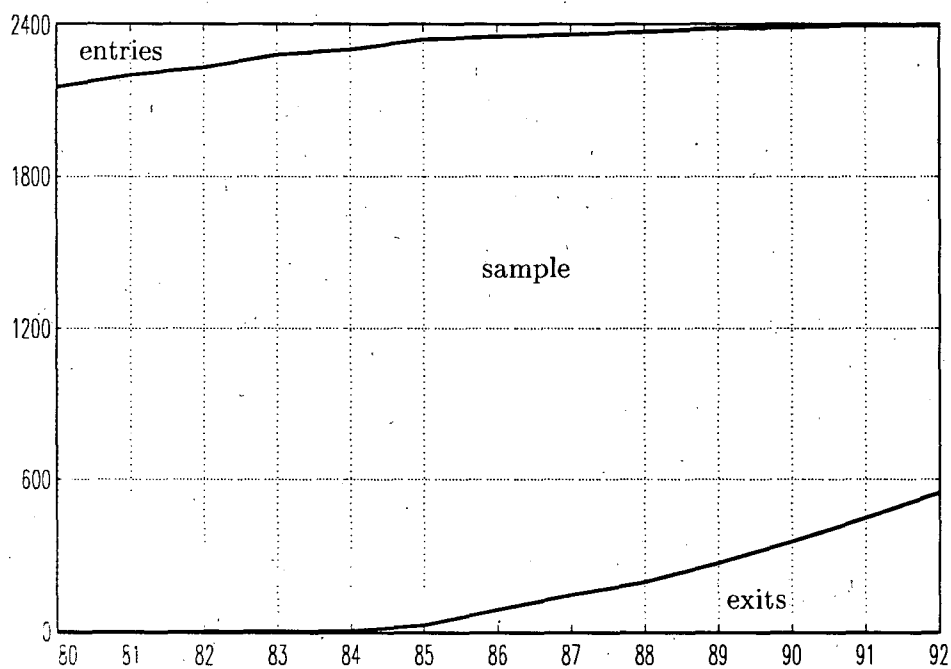
Source: Sectoral national accounts.

**Table 23: Sectoral output, employment, prices, and investment**

sector	$\Delta \ln l^s$	$IY^s$	$\Delta \ln y^s$	$\Delta \ln p^s$	$\Delta \ln s^s$
21	-0.016	0.061	0.002	0.033	0.031
22	-0.034	0.048	0.014	-0.006	-0.002
23	-0.016	0.052	-0.013	0.039	0.023
24	-0.035	0.015	-0.038	0.066	0.002
25	0.002	0.052	0.028	0.018	0.033
26	-0.018	0.052	0.044	-0.016	0.013
27	0.000	0.086	0.030	0.010	0.040
28	-0.009	0.047	0.005	0.031	0.038
31	0.002	0.029	-0.003	0.041	0.038
32	0.007	0.046	0.010	0.034	0.049
33	0.006	0.056	0.028	0.029	0.068
34	0.005	0.049	0.039	0.014	0.057
35	-0.002	0.041	0.010	0.030	0.044
37	0.005	0.041	0.029	0.028	0.043
38	0.011	0.047	0.022	0.035	0.057
411	-0.014	0.057	-0.013	0.033	0.029
412	-0.008	0.074	0.020	0.010	0.038
42	-0.007	0.032	-0.010	0.050	0.035
43	-0.019	0.044	0.014	0.029	0.032
441	0.006	0.057	0.026	0.032	0.060
442	0.012	0.063	0.018	0.031	0.052
45	0.031	0.060	0.050	0.023	0.070
46	-0.060	0.023	-0.034	0.026	0.004
471	-0.039	0.044	-0.008	0.020	0.014
472	-0.039	0.016	-0.013	0.027	0.020
51	-0.006	0.036	0.000	0.034	0.028
52	-0.035	0.016	-0.004	0.040	0.046
total	-0.004	0.048	0.013	0.027	0.041

Source: Sectoral national accounts. The sector definitions are contained in table 18.

**Figure 9: Attrition**



**Table 24: Attrition**

year	entries	exits	sample	response
1980		0	2156	2156
1981	47	0	2203	2193
1982	29	3	2232	2222
1983	53	1	2282	2271
1984	19	20	2300	2286
1985	41	63	2321	2319
1986	11	57	2269	2267
1987	9	52	2221	2219
1988	10	73	2179	2175
1989	12	85	2118	2116
1990	5	95	2038	2037
1991	6	99	1949	1949
1992	1		1851	1851
$\Sigma$	243	548	28119	28061

Source: ifo firm panel

**Table 25: Price, output, and employment changes**

	prod	proc	<i>IY</i>	prod <sup>s</sup>	proc <sup>s</sup>	cat <sub>1</sub>
<b>prices</b>						
ps > 0	0.172 ( 7.5)	0.049 (2.2)	-0.148 (-1.0)	0.521 ( 5.8)	0.150 ( 1.1)	0.537
ps ≥ 0	0.185 ( 6.4)	0.020 (0.7)	-0.368 (-2.1)	1.453 (13.3)	-0.140 (-0.8)	0.854
ps/obs	0.022 ( 6.2)	0.001 (0.2)	-0.028 (-1.1)	0.062 ( 4.4)	-0.049 (-2.3)	
pc > 0	0.075 ( 3.1)	0.054 (2.3)	0.076 ( 0.5)	-0.530 (-5.6)	0.381 ( 2.7)	0.707
pc > 1	-0.034 (-1.5)	0.021 (0.9)	-0.197 (-1.2)	-1.339 (-14.7)	-0.018 (-0.1)	0.369
<b>employment</b>						
ls > 0	0.272 ( 9.2)	0.088 (3.1)	0.728 ( 4.0)	0.101 ( 0.9)	0.118 ( 0.7)	0.145
ls ≥ 0	-0.017 (-0.7)	0.033 (1.4)	0.500 ( 2.8)	-0.516 (-5.3)	-0.105 (-0.7)	0.721
ls/obs	0.024 ( 4.2)	0.016 (2.8)	0.199 ( 5.1)	-0.075 (-3.4)	-0.014 (-0.4)	
lc > 0	0.167 ( 7.3)	0.030 (1.4)	-0.016 (-0.1)	0.428 ( 4.8)	0.223 ( 1.7)	0.436
lc > 1	0.137 ( 5.3)	0.052 (2.1)	-0.535 (-2.7)	0.413 ( 4.1)	0.298 ( 2.0)	0.216
<b>output</b>						
ys > 0	0.158 ( 6.6)	0.121 (5.2)	0.541 ( 3.4)	-0.248 (-2.6)	0.163 ( 1.2)	0.328
ys ≥ 0	0.090 ( 3.8)	0.086 (3.7)	0.568 ( 3.5)	0.152 ( 1.7)	-0.125 (-0.9)	0.593
ys/obs	0.030 ( 6.8)	0.025 (5.9)	0.096 ( 3.2)	-0.023 (-1.3)	-0.011 (-0.4)	
yc > 0	0.036 ( 1.5)	0.055 (2.4)	0.122 ( 0.7)	-0.903 (-9.6)	0.549 ( 4.0)	0.688
yc/obs > :5	0.028 ( 1.1)	0.036 (1.4)	-0.129 (-0.7)	-0.737 (-7.4)	0.303 ( 2.0)	0.206

Notes: binary probit models, OLS for ps/obs, ls/obs, and ys/obs.  
sample: 1981-1992, time and size dummies were included.

cat<sub>1</sub> is share of observations for category 1, pc denotes the number of price changes per year, ps denotes the difference between the number of increases and decreases per year, obs is the number of observations per year. The variables for employment and output are defined correspondingly

Table 26: Output increases

endogenous variable: output increase, $y^+$							
month	prod	proc	<i>IY</i>	prod <sup>s</sup>	proc <sup>s</sup>	$\bar{l} < 50$	$\bar{l} > 1000$
jan	0.080 ( 2.8)	0.135 ( 4.9)	0.032 ( 0.2)	-0.693 ( -6.3)	0.151 ( 0.9)	-0.202 (-4.8)	-0.016 (-0.5)
feb	0.140 ( 4.9)	0.099 ( 3.6)	0.133 ( 0.7)	-0.371 ( -3.3)	0.356 ( 2.2)	-0.044 (-1.1)	-0.092 (-3.0)
mar	0.089 ( 3.3)	0.134 ( 5.1)	0.607 ( 3.5)	-0.404 ( -3.8)	-0.155 (-1.0)	0.020 ( 0.5)	-0.027 (-0.9)
apr	0.103 ( 3.5)	0.063 ( 2.2)	0.504 ( 2.7)	-0.629 ( -5.4)	0.334 ( 2.0)	0.031 ( 0.8)	-0.073 (-2.2)
may	0.053 ( 1.8)	0.077 ( 2.6)	0.750 ( 4.1)	-0.477 ( -4.1)	-0.175 (-1.0)	-0.046 (-1.1)	-0.066 (-2.0)
jun	0.067 ( 2.3)	0.054 ( 1.9)	0.318 ( 1.7)	-0.175 ( -1.5)	-0.184 (-1.1)	-0.106 (-2.4)	-0.049 (-1.5)
jul	0.101 ( 3.3)	0.049 ( 1.6)	0.547 ( 2.9)	-0.105 ( -0.9)	-0.501 (-2.8)	-0.025 (-0.6)	-0.029 (-0.8)
aug	0.034 ( 1.1)	0.097 ( 3.2)	-0.243 (-1.1)	-0.688 ( -5.6)	0.139 ( 0.8)	-0.181 (-4.0)	-0.123 (-3.5)
sep	-0.114 ( 4.1)	0.125 ( 4.7)	0.043 ( 0.2)	-0.971 ( -9.0)	0.688 ( 4.3)	-0.181 (-4.5)	-0.093 (-3.0)
oct	0.090 ( 3.1)	0.079 ( 2.9)	0.184 ( 1.0)	-0.472 ( -4.2)	0.398 ( 2.4)	-0.151 (-3.6)	-0.030 (-1.0)
nov	0.107 ( 3.5)	0.099 ( 3.4)	-0.634 (-2.7)	-0.457 ( -3.9)	0.483 ( 2.8)	-0.007 (-0.2)	-0.074 (-2.2)
dec	0.144 ( 4.5)	0.009 ( 0.3)	0.002 ( 0.0)	-0.004 ( 0.0)	0.140 ( 0.8)	0.031 ( 0.7)	-0.032 (-0.9)
endogenous variable: output increase at least once a year, $y1^+$							
	0.103 ( 4.4)	0.130 ( 5.8)	0.345 ( 2.2)	-0.916 (-10.1)	0.418 ( 3.1)	-0.037 (-1.2)	-0.123 (-4.9)
endogenous variable: output increase more than once a year							
	0.142 ( 6.1)	0.133 ( 5.9)	0.301 ( 1.9)	-0.817 ( -9.0)	0.322 ( 2.4)	-0.070 (-2.2)	-0.102 (-4.0)

Notes: binary probit models,  
sample: 1981-1992, time dummies (1981-1991) were included

Table 27: Output decreases

endogenous variable: output decrease, $y_1^-$							
month	prod	proc	IY	prod <sup>s</sup>	proc <sup>s</sup>	$\bar{l} < 50$	$\bar{l} > 1000$
jan	-0.065 (-2.4)	-0.061 (-2.3)	-0.024 (-0.1)	-0.318 (-3.0)	0.131 (0.8)	0.217 (6.1)	-0.095 (-3.1)
feb	-0.115 (-4.0)	-0.035 (-1.2)	-0.313 (-1.6)	-0.300 (-2.7)	-0.402 (-2.4)	0.117 (3.1)	-0.036 (-1.1)
mar	-0.082 (-2.7)	-0.069 (-2.3)	-0.639 (-2.7)	-0.207 (-1.7)	0.042 (0.2)	-0.007 (-0.2)	-0.028 (-0.8)
apr	-0.024 (-0.9)	0.006 (0.2)	-0.726 (-3.4)	-0.233 (-2.1)	0.198 (1.2)	0.025 (0.7)	-0.132 (-4.1)
may	0.021 (0.7)	-0.002 (-0.1)	-0.650 (-3.1)	-0.190 (-1.7)	0.288 (1.8)	-0.005 (-0.1)	-0.143 (-4.6)
jun	-0.058 (-2.0)	0.014 (0.5)	-0.363 (-1.8)	-0.447 (-4.1)	0.415 (2.5)	0.040 (1.0)	-0.078 (-2.5)
jul	-0.037 (-1.3)	-0.001 (0.0)	-0.301 (-1.6)	-0.692 (-6.6)	0.629 (4.0)	-0.014 (-0.4)	-0.098 (-3.3)
aug	-0.025 (-0.9)	0.000 (0.0)	-0.012 (-0.1)	-0.294 (-2.8)	0.425 (2.8)	0.052 (1.4)	-0.074 (-2.5)
sep	-0.073 (-2.5)	-0.030 (-1.0)	-0.152 (-0.8)	0.151 (1.3)	-0.060 (-0.4)	0.116 (3.0)	-0.085 (-2.7)
oct	-0.061 (-2.2)	-0.060 (-2.2)	-0.363 (-1.8)	-0.158 (-1.4)	0.122 (0.7)	0.059 (1.5)	-0.102 (-3.2)
nov	-0.040 (-1.4)	-0.030 (-1.1)	0.402 (2.3)	-0.424 (-3.9)	-0.052 (-0.3)	0.074 (2.0)	-0.079 (-2.5)
dec	-0.017 (-0.7)	-0.052 (-2.0)	0.440 (2.6)	-0.649 (-6.5)	0.095 (0.6)	0.063 (1.8)	-0.069 (-2.4)
endogenous variable: output decrease at least once a year, $y_1^-$							
	-0.051 (-2.2)	-0.015 (-0.7)	-0.179 (-1.1)	-0.752 (-8.1)	0.331 (2.4)	0.090 (2.7)	-0.153 (-6.0)
endogenous variable: output decrease more than once a year							
	-0.057 (-2.5)	0.007 (0.3)	-0.268 (-1.7)	-0.585 (-6.5)	0.277 (2.1)	0.148 (4.6)	-0.121 (-4.7)

Notes: binary probit models,  
sample: 1981-1992, time dummies (1981-1991) were included

**Table 28: Sample selection**

<i>DUC</i>	prod	proc	<i>IY</i>	prod <sup>s</sup>	proc <sup>s</sup>	leaver	exit <sub>t</sub>	exit <sub>t+1</sub>
endogenous variable: price increase at least once a year, $p1^+$								
0.369 ( 4.5)	0.139 ( 6.0)	0.053 ( 2.3)	-0.267 (-1.7)	0.082 ( 0.9)	0.384 ( 2.8)			
0.324 ( 3.9)	0.140 ( 6.0)	0.049 ( 2.1)	-0.307 (-2.0)	0.091 ( 1.0)	0.352 ( 2.6)	-0.188 (-6.5)		
0.360 ( 4.2)	0.147 ( 6.1)	0.045 ( 1.9)	-0.249 (-1.5)	0.009 ( 0.1)	0.470 ( 3.3)		-0.216 (-2.4)	-0.215 (-2.9)
endogenous variable: price decrease at least once a year, $p1^-$								
0.000 ( 0.0)	-0.174 (-6.5)	-0.004 (-0.1)	0.126 ( 0.7)	-1.584 (-15.4)	0.164 ( 1.1)			
0.016 ( 0.2)	-0.175 (-6.5)	-0.001 (-0.0)	0.131 ( 0.8)	-1.590 (-15.5)	0.171 ( 1.1)	0.052 (1.6)		
-0.028 (-0.3)	-0.176 (-6.2)	-0.009 (-0.3)	-0.057 (-0.3)	-1.584 (-14.7)	0.176 ( 1.1)		-0.135 (-1.2)	0.064 (0.7)
endogenous variable: employment increase at least once a year, $l1^+$								
0.971 ( 8.9)	0.256 ( 8.9)	0.073 ( 2.6)	0.560 ( 3.1)	0.077 ( 0.7)	0.196 ( 1.2)			
0.942 ( 8.6)	0.256 ( 8.8)	0.070 ( 2.5)	0.529 ( 2.9)	0.095 ( 0.8)	0.156 ( 0.9)	-0.212 (-5.4)		
0.941 ( 8.4)	0.266 ( 9.0)	0.070 ( 2.5)	0.488 ( 2.6)	0.077 ( 0.7)	0.204 ( 1.2)		-0.525 (-4.0)	-0.260 (-2.7)
endogenous variable: employment decrease at least once a year, $l1^-$								
-1.568 (-17.7)	0.051 ( 2.0)	0.016 ( 0.7)	-0.376 (-2.1)	0.554 ( 5.6)	0.034 ( 0.2)			
-1.535 (-17.3)	0.051 ( 2.0)	0.017 ( 0.7)	-0.341 (-1.9)	0.550 ( 5.5)	0.056 ( 0.4)	0.176 (5.8)		
-1.513 (-16.5)	0.041 ( 1.6)	0.005 ( 0.2)	0.282 (-1.5)	0.623 ( 6.0)	-0.141 (-0.9)		0.549 (5.9)	0.365 (4.7)
endogenous variable: employment changes, $\Delta \ln l$								
0.090 (13.9)	0.007 ( 4.1)	0.002 ( 1.0)	0.133 (10.5)	-0.029 (-4.2)	0.029 ( 2.8)			
0.086 (13.3)	0.007 ( 4.0)	0.002 ( 0.9)	0.127 (10.0)	-0.028 (-4.0)	0.027 ( 2.6)	-0.020 (-8.5)		
0.087 (13.1)	0.008 ( 4.1)	0.002 ( 1.3)	0.139 (10.5)	-0.027 (-3.7)	0.033 ( 3.1)		-0.021 (-2.0)	-0.030 (-4.6)
endogenous variable: sales changes, $\Delta \ln s$								
0.067 ( 7.3)	0.006 ( 2.3)	0.001 ( 0.3)	0.190 (10.7)	0.011 ( 1.1)	-0.016 (-1.1)			
0.063 ( 6.9)	0.006 ( 2.3)	0.000 ( 0.2)	0.184 (10.4)	0.012 ( 1.2)	-0.019 (-1.3)	-0.020 (-6.0)		
0.063 ( 6.7)	0.005 ( 1.8)	0.001 ( 0.4)	0.194 (10.5)	0.009 ( 0.9)	-0.008 (-0.6)		-0.013 (-0.9)	-0.023 (-2.5)

Notes: See text for explanations. Size dummies not reported.  
The sample for the equations with exits is 1981-1991.