DETERMINANTS OF INNOVATION BEHAVIOUR AND INVESTMENT ESTIMATES FOR WEST-GERMAN MANUFACTURING FIRMS

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In this paper, the determinants of innovation behaviour and investment are explored with a large micro-data panel from West-German manufacturing firms. The estimates are discussed within a microeconomic model with monopolistic competition, demand uncertainty and a delayed adjustment of capacities and the production technology. The estimates reveal positive firm-size effects which hint towards scale economies associated with innovations. Market power promotes innovations but not investment, and exporters innovate more but exhibit less investment expenditures. Finally, excess demand promotes innovations. This indicates a complementarity of innovations and investment and hints towards permanent productivity effects of temporary demand shocks.

Keywords: Endogenous innovations and investment; Market structure; Business cycle

JEL No.: D21, O31

1 INTRODUCTION

The basic premise of most endogenous growth models is that technological progress is driven by innovations.1 Firms innovate in order to reduce costs or to increase demand. Since the knowledge incorporated in innovations is non-rival and only partially excludable, firm size and market structure are important determinants of innovation behaviour.2 On the one hand, large firms on monopolistic markets must fear less imitation from competitors and gain more from scale economies associated with innovations. Small firms on competitive markets, on the other hand, are forced to utilize the best available production technique and to develop better products. However, the market structure itself is endogenous.3 Firms develop differentiated products to earn more profits through a temporary monopolistic situation on the product market. In the long run, innovations of other firms destroy monopolistic rents, and the process of creative destruction is the driving force of endogenous technological change.4

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1 See Romer (1990) and Grossman, Helpman (1994).
2 See Kamien, Schwarz (1975), Cohen, Levin (1989), Scherer, Ross (1990) and Aghion et al. (2002).
4 See Aghion, Howitt (1992).
A first topic of the paper is the analysis of market structure effects on innovations. It is argued that market power increases the capability to introduce innovations, but the returns from innovations are larger on competitive markets. Besides firm size, a measure of market power is derived from the price-setting behaviour of the firm, i.e., information about the competitive situation on the market is deduced from firms’ market behaviour. Another information about the market is that the respective product is exported. A second topic is the analysis of the relation of innovations and the business cycle. Positive demand effects on innovations can be derived from complementarities with capital investment, negative effects of excess demand stem from arguments of intertemporal substitution. Note that demand effects on innovations imply that changes in demand affect output and productivity permanently.

This paper discusses estimates of the determinants of innovation behaviour and investment within a model of monopolistic competition on the product market and a delayed adjustment of innovations and investment. The model permits to discuss competition and business cycle induced effects consistently within the theoretical framework. The innovation decision is treated analogously to the investment decision, and complementarities of innovations and capital investment are taken into account. The estimates employ a unique data panel with 2405 firms from West-German manufacturing, 1980–1992. The data stem from the surveys of the ifo Institut. The business survey contains the qualitative information, whether a firm has implemented product and/or process innovations, as well as data on market behaviour, capacity constraints and demand conditions. The innovation survey contains quantitative data on innovation expenditures. These data were matched with quantitative data on investment from the investment survey.

2 THEORETICAL FRAMEWORK

2.1 Investment and the Business Cycle

The analysis is based on a framework of monopolistic competition on the product market and a delayed adjustment of capacities and innovations. In order to distinguish demand shifts, the price elasticity of demand, and demand uncertainty, a log-linear demand curve for the firm’s product is assumed,

$$\ln YD = \eta \cdot \ln p + \ln Z + \varepsilon, \quad \eta < -1, \quad E(\varepsilon) = 0, \quad \text{Var}(\varepsilon) = \sigma^2.$$  

(1)

Demand $YD$ depends negatively on the price $p$ with elasticity $\eta$, exogenous and predetermined factors incorporated in $Z$ and an error term $\varepsilon$ which is not known at the time of the innovation and investment decision. It is assumed that $\varepsilon$ exhibits positive autocorrelation, i.e., firms expect that demand shocks partly persist. Product innovations affect the demand curve via $Z$, $\eta$, and $\sigma$. New or better products increase the level of demand and protect the firm from competition. Short-run supply $YS$ is determined by a limitation production function with capital $K$ and labour $L$ as inputs,

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

(2)

$YC$ are capacities, $YL$ is the employment constraint of the short-run production function, and $\pi_l$, $\pi_k$ are the productivities of labour and capital. The factor productivities depend on the

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6See Blanchard, Kiyotaki (1987) and Smolny (1998a,b).
capital-labour ratio $k$ and production efficiency $\theta$, i.e. $\pi_l = \pi_l(k, \theta)$, $\pi_k = \pi_k(k, \theta)$. Investment determines capacities, process innovations affect efficiency, and capital-labour substitution is possible only in the long run (putty-clay technology). For the short-run outcome, two cases can be distinguished.\footnote{For a detailed discussion of the theoretical model and some estimates of the short-run adjustment, see Smolny (1998a, b).}

1. In boom situations with excess demand, capacities limit supply and the firm increases the price (see Fig. 1).
2. In recession periods with sufficient capacities, the price adjustment is bounded by unit labour costs $w/\pi_l$ and the price elasticity of demand $\eta$,

$$p(w) = \frac{w}{\pi_l \cdot (1 + 1/\eta)}, \quad w := \text{wage rate.} \tag{3}$$

In case of insufficient demand, underutilization of capacities occurs. The main outcome of the short-run model are the possibility of capacity constraints and a lower bound for prices. Note that a low absolute value of the price elasticity of demand $|\eta|$ favours quantity adjustments against price adjustments.

In the long run, the firm decides on capacities and innovations under uncertainty about demand. Figure 1 hints towards the main driving force of investment. Marginal returns to capital are achieved only, if capacities become the binding constraint for output. In recession periods with slack demand, the marginal product of capacities is 0. In boom periods with sufficient demand, more profits could be earned with higher capacities. With autocorrelated demand shocks, firms invest in case of capacity constraints, and the choice of capacities can be understood as the choice of the optimal probability of capacity constraints. The following properties can be derived.\footnote{A detailed discussion of the theoretical model is contained in Smolny (2002).}

Optimal capacities are determined as

$$\ln YC = \eta \cdot \ln p(w) + \ln Z + \bar{\varepsilon} \left(\eta, \sigma, \frac{c}{\pi_l w}\right), \quad c := \text{capital costs.} \tag{4}$$

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{output_prices.png}
\caption{Output and prices.}
\end{figure}
Eq. (4) is the base of the empirical estimates of capital investment. Optimal capacities depend loglinear on the demand shift $Z$, expected demand shifts increase all quantities proportionally and do not affect prices or relative quantities. Higher factor costs increase expected prices proportionally, i.e., the model exhibits linear homogeneity both in prices and quantities. Higher relative capital costs reduce optimal capacities through capital-labour substitution, less competition reduces capacities through higher prices, and more uncertainty reduces capacities through higher average costs of capital.

The adjustment of capacities can be understood as an error correction model for investment. A positive demand shock increases output and capacity utilization today. If the firm expects that the higher demand persists (autocorrelated demand shocks), it will, with a delay, increase capacities, i.e., capacities adjust, if capacity utilization differs from the optimum. Finally, credit market imperfections can be introduced by specifying a constraint on the borrowing. In this case, the firm chooses a lower capital stock. Investment depends positively on cash flow and retained profits, i.e., unexpected demand shocks in the past and the degree of competition exhibit an additional effect.

### 2.2 Innovations and the Business Cycle

Innovations can be understood as investments in knowledge capital, analogously to capital investment. In the empirical model, it is distinguished between the implementation of product and process innovations, and process innovations are distinguished from capital investment. Capital investment stands for quantity effects of homogeneous capital, process innovations affect the productivities of labour and capital through efficiency $\theta$, and product innovations affect the demand curve. A successful product innovation implies that the quality of the product increases, and demand increases. In addition, new and better products are probably more specialized which protects the firm from competition. In the model, it can be distinguished between effects on the level of demand $Z$, effects on the price elasticity of demand $\eta$, and effects on demand uncertainty $\sigma$.

Complementarities of innovations and capital investment are expected. First, new products often require new production processes, and new production processes permit to produce better products. Second, both product and process innovations may be complementary with capital investment. The introduction of a new production method requires capital investment. These complementarities imply that the probability to implement an innovation depends positively on the amount of investment, and the amount of investment depends positively on the implementation of innovations. Taken differently, the same incentives and constraints that drive capital investment also affect innovation behaviour, and the determinants of innovations also affect investment.

This connects the microeconomic analysis of the determinants of innovations to the macroeconomic discussion of the relation of growth and the business cycle. If the business cycle affects innovations, changes in aggregate demand affect output and productivity permanently. The dynamic adjustment model of capacities provides a consistent framework to discuss demand-induced effects on innovations.

1. The complementarity of capital investment and innovations implies a positive effect from capacity utilization $U$ and demand expectations $Z$ on innovations.

9The distinction between product and process innovations is clear only at the micro level. At the aggregate level, a product innovation of one firm can be a process innovation for another firm.

10In Smolny (1998b), it was found that product innovations increase the level of demand $Z$ and reduce competition, i.e., reduce the absolute value of the price elasticity of demand $|\eta|$.

– Second, extraordinary cash flows and higher prices $p$ permit to finance a larger share of innovation expenditures from retained profits in period of excess demand.
– Third, increasing demand in the past $e$, $Z$ indicates growing markets also in the future which favours innovations which incur fixed costs.
– These arguments stand against opportunity costs and intertemporal substitution which imply positive effects on innovations from periods of slack demand. Non-production activities such as reorganizations of production processes, R&D and training exhibit less opportunity costs in case of excess capacities.\(^\text{12}\)

Therefore, the effect of the business cycle on innovations cannot be derived unambiguously from theoretical arguments.

### 2.3 Innovations and Market Structure

A main difference between capital investment and innovations, \textit{i.e.} investment in knowledge, is that the costs of the former are largely variable costs, while the latter impose at least partially a fixed cost. This implies that large firms exhibit a relative advantage as compared with small firms, since they can spread costs on a larger quantity of output. A related argument in favour of large firms are internal spillovers and complementarities of R&D activities, or economies of scope.\(^\text{13}\) A third argument is based on the risk associated with innovations and credit market imperfections. Due to asymmetric information, adverse selection and moral hazard, commercial banks hesitate to finance risky innovation projects of small firms.\(^\text{14}\) Large firms have easier access to internal finance; in addition, they perform many innovation projects which spreads the risk and reduces the risk for the bank.

Since Schumpeter, the general impression of economic analyses of the effects of competition on innovations is that market power tends to reduce the incentive but enhances the ability to innovate.\(^\text{15}\) According to Schumpeter, the ability to earn large profits and expectations of a temporary monopoly cause firms to introduce innovations.\(^\text{16}\) One argument in favour of innovations on monopolistic markets are monopoly profits that permit an easier finance of risky innovation projects. In addition, if product innovations imply a simple shift of demand $Z$, less competition implies a larger increase in profits as compared with the competitive case. On the other hand, more competition implies that a firm can achieve larger increases in market shares with a reduction of costs and the price. The same holds for product innovations, if they imply that the firm can sell the same quantity at a higher price.\(^\text{17}\)

In addition, product innovations change the market structure, and the intended reduction of the price elasticity of demand is an important incentive to innovate. It is not clear how existing market power changes the incentives of innovation activities in this case. On the one hand, it can be argued that on highly competitive markets, temporary market power vanishes quickly, \textit{i.e.} the incentive to innovate is low. On the other hand, on markets with a small number of (large) firms, each firm watches each others innovation activities closely and reacts on others innovations. Then, the incentive to innovate is smaller on oligopolistic markets.

\(^\text{12}\)For a detailed discussion, see Aghion, Saint-Paul (1993).
\(^\text{13}\)See Cohen, Levin (1989).
\(^\text{15}\)It should be distinguished between effects of firm size and effects of market power measured by the price elasticity of demand. Both capture to some extent market power, but the arguments are different. The (common) analysis in terms of market shares does not allow to identify the different effects of firm size, on the one hand, and market power, on the other hand, on innovations.
\(^\text{16}\)For an overview, see Kamien, Schwarz (1975) and Cohen, Levin (1989).
\(^\text{17}\)In the model here, process innovations that affect costs proportionally and product innovations that affect only the level of demand are basically equivalent. Aghion \textit{et al.}, (2002) recently established a U-shaped relationship between innovations and competition.
In addition, monopolists have less incentives to introduce new products, because new products destroy the monopolistic rents of existing products. A summary of the expected effects on innovations and capital investment is contained in Table I. The aim of the empirical work is to test the hypotheses of the theoretical model and to estimate those effects which are ambiguous from theoretical arguments.

3 EMPIRICAL ANALYSIS

3.1 Data and Empirical Specification

The data base for the estimation of the determinants of innovation behaviour and investment is a unique panel of West-German manufacturing firms over 13 years, 1980–1992. The data stem from three different surveys of the ifo Institut, München. The panel consists of 2405 observation units from 1982 firms. Innovations are defined as novelties or essential improvements of the product or the production technique.

– In the business survey, the firms are asked, whether (within the year for a specific product) product and/or process innovations were implemented. Most firms in the panel innovate, at least in some years. The relative frequency of product and process innovations is quite evenly distributed within the range $0, 1$.

– The innovation survey supplements qualitative data on innovation activities and quantitative data on innovation expenditures. Note that the indicator in the innovation survey captures the long-run propensity to innovate, while the question in the business survey captures the timing of the introduction of a new product or the implementation of a new production technique. The average share of innovation expenditures in sales is slightly below 3 percent. For small firms (less than 100 employees) the innovation rate is about 2 percent, for large firms (more than 1000 employees), it exceeds 6 percent. Remarkable is also the large variance of innovation expenditures within the size classes.

– Data on investment and sales are available from the investment survey. On average, the share of investment in sales is about 5 percent (about 4 percent for equipment and 1 percent for structures) which corresponds roughly to the respective figures for total manufacturing. The averages do not reveal important differences according to firm size, but the variance of investment rates is lower for large firms.

The business survey also contains detailed monthly and quarterly information on the short-run demand conditions. First, it contains quarterly data on the degree of capacity utilization $U$. Average capacity utilization in the sample is about 83 percent, the standard deviation is about 13 percent. For investment, this describes the basic indicator of capacity shortages which should drive the adjustment. Innovations should depend on capacity utilization through the complementarity with capital investment and through cash flows. For the estimates, the average capacity utilization during the year preceding the implementation of an...
innovation/an investment project is employed. In addition, an explicite dummy variable for capacity constraints is calculated which is 1 for those observations where \( U > 0.95 \).

A measure of the volatility of demand shocks at the firm level is calculated as the relative frequency of demand changes \( \sigma_{TD} \). In the questionnaire, the firms are asked whether the demand situation for their product is better, unchanged or worse, as compared with the preceding month. \( \sigma_{TD} \) is defined as the sum of the ‘better’ and ‘worse’ responses per year, relative to the total number of observations per year. A direct indicator of growing markets are the medium-run demand expectations relative to the total number of observations per year. A direct indicator of growing markets are asked about their estimate of the general development of the product market in the medium run (5 years). For the estimates, 2 dummy variables are calculated for a growing market \( Z^+ \) and for a shrinking market \( Z^- \); a stagnating market is the reference case.

In the monthly business survey questionnaire, the firms are also asked about realized price changes, as compared with the preceding month. The information is qualitative, i.e. it is distinguished between increase, no change and decrease. The data reveal that the firms reported about one price increase per year and about one price reduction every second year, on average. For the empirical analysis, annual net price increases \( \Delta_p \) are calculated as the difference of the annual number of increases and decreases, relative to the number of observations per year. Realized price increases indicate favourite demand conditions and might also indicate market power. A related indicator of the competitive situation on the market is the frequency of price changes \( \sigma_p \). In case of adjustment costs for prices, the frequency of price changes can serve as an indicator of the price elasticity of demand. Low competition favours quantity adjustments against price adjustments, i.e. a low frequency of price changes indicates a monopolistic/oligopolistic market.\(^{19}\)

Firm size is specified with dummies according to the average number of employees \( \tilde{I} \). Although large firms are over-represented in the survey, as compared with total manufacturing, the sample consists mainly of small and medium-size firms. About 1/3 of the observations stem from firms with less than 100 employees, and only 10 percent of the data stem from firms with more than 1000 employees. Firm size should favour innovations through fixed cost arguments and though the financing conditions. A firm-size effect on investment could stem from credit market imperfections and from a complementarity with innovations. In addition, a diversification dummy is included for those firms, where product level employment is below half of firm-level employment (about 1/3 of the sample).\(^{20}\) A positive effect from diversification would indicate the importance of credit market imperfections and/or internal spillovers of R&D activities.

A final indicator of market structure, market size, and technological opportunity is given by the information, whether the respective product is also exported. About 80 percent of the firms are exporters, nearly all large firms export their product. This variable might capture the competitiveness and therefore the quality of the product, i.e. indicates the inventive capability of the firm. In addition, the world market is a source of spillovers. Finally, a complete set of 11 time dummies is always included in the estimates (not reported in the tables). These dummies shall capture effects from interest rates, wages, and prices of raw materials and intermediates; the data-set does not contain information about those variables at the firm level.\(^{21}\)

In the empirical model, identification is sought through lagged values of the explanatory variables, i.e. the restrictions from the theoretical model are exploited for the estimation.

\(^{19}\)A straightforward measure of competition is the price/cost relation. However, the data-set does not contain information on firm-specific cost conditions. In addition, past periods’ profits can result from unexpected demand shocks on the market.

\(^{20}\)Data on investment for diversified firms are not available, because the investment survey refers to the firm level, only.

\(^{21}\)Estimates with 2-digit sectoral dummies are available on request. The yield similar qualitative effects. Panel attrition in the ifo data is discussed in Smolny (1998b).
Demand shocks are autocorrelated, and investment and innovations adjust delayed with respect to demand. Therefore lagged values of demand, output, prices and capacity utilization are treated as predetermined for innovation behaviour and investment. The endogenous variables in the empirical model are the probability of an implementation of an innovation, the probability of innovation activities, the amount of innovation expenditures relative to sales and the share of investment in sales. In addition, product and process innovation are distinguished, and results for equipment investment and investment in structures are depicted. According to the proposed simultaneousness of the investment and innovation decision, and complementarities of innovations and investment, the explanatory variables in the empirical model are the same for investment and for innovation behaviour. The bivariate correlation of innovations and investment and the autocorrelation of innovation behaviour are shown in cross-tabulations. 22

3.2 Innovation Behaviour and Investment

Some direct information on complementarities and the dynamics of innovation behaviour and investment are shown in Table II. In the first columns, the (relative) numbers of product and process innovators are depicted. The sample consists of 22237 observations from 2399 firms. In about one half of the observations, the firms reported a product or a process innovation, respectively, i.e. firms implemented a product and a process innovation every second year, on average. In about 1/3 of the observations, the firms reported no innovation. 23

The average share of investment in sales \((i/s)\) for all firms is about 5 percent. As expected, investment was nearly 1 percentage point higher for firms that implemented a process innovation. The data do not reveal that firms invest more, if they implement a product innovation, i.e. they indicate a complementarity of process innovations and investment, but no direct complementarity of product innovations and investment. 24

The investment rates in the subsequent period \((i/s)_{t+1}\) show that the largest correlation of innovations and investment is contemporaneous, i.e. the data do not indicate that investment follows innovations. Note, however that these correlations should not be interpreted in a causal sense. They also reflect a similar development of the determinants of innovation behaviour and investment. The data for the average shares of innovation expenditures in sales \((ie/s)\) reveal that innovation rates are higher

### TABLE II Innovations and Investment.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Investment</th>
<th>Innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(i/s) (_t)</td>
<td>(i/s) (_{t+1})</td>
</tr>
<tr>
<td>Product</td>
<td>0.051</td>
<td>0.050</td>
</tr>
<tr>
<td>Process</td>
<td>0.059</td>
<td>0.053</td>
</tr>
<tr>
<td>No innovation</td>
<td>0.044</td>
<td>0.049</td>
</tr>
<tr>
<td>All firms</td>
<td>0.051</td>
<td>0.051</td>
</tr>
</tbody>
</table>

Product: product innovation implemented.
Process: process innovation implemented.
No innovation: neither product nor process innovation implemented.
\((ie/s)\): share of innovation expenditures in sales.
\((i/s)\): share of investment expenditures in sales.

22The estimation of a dynamic simultaneous model of innovation behaviour and investment is beyond the scope of the paper. See e.g. Pohlmeier (1992) and Flaig, Stadler (1996).
23Only in about 15 percent of the cases, the firms reported a product/process innovation only.
24Firms that implemented a product innovation only invested even less than firms that did not innovate; the largest investment rates (7 percent) are observed for those firms that implemented a process innovation only (not reported).
both for product and for process innovators. The innovation rate is about 3 percent for all firms, about 4 percent for firms that implemented an innovation, and only 1.3 percent for firms that did not implement an innovation. Table III contains some informations about the complementarity of product and process innovations:

- About 72 (66) percent of those firms that implemented a process (product) innovation also implemented a product (process) innovation in the same year, as compared with only 50 (46) percent for all firms. That means, product and process innovations are correlated.
- In addition, innovation behaviour is autocorrelated. 74 (67) percent of those firms that implemented a product (process) innovation in the current year also implemented a product (process) innovation in the subsequent year, as compared with only 51 (47) percent for all firms; Correspondingly, only about 1/4 of those firms which did not innovate in the current year implemented a product or a process innovation in the subsequent year.
- Finally, innovative firms were more successful. They exhibited a higher capacity utilization and more sales growth. Average sales growth (capacity utilization) for all firms was 3.5 percent (83 percent), innovators exhibited about 1 percentage point more sales growth and a 2 percentage points higher capacity utilization rate.

These results together hint towards complementarities of process innovations and investment. A corresponding direct correlation of product innovations and investment is not found, but product innovations are correlated with process innovations. The autocorrelation of innovation behaviour is consistent with the argument that past innovation behaviour enhances (indicates) the innovative capability of the firm. However, these correlations should not be interpreted in a causal sense. They might also result from (auto-)correlation of the determinants of innovation behaviour and investment.

### 3.3 Estimation Results

In Table IV, estimation results of binary probit models for the implementation of innovations and innovation activities are reported. The table also contains estimates of Tobit models for innovation and investment rates. Depicted are the coefficients and the corresponding t-values (in parantheses). In Table V, the results for product and process innovations and investments in structures and equipment are shown. The sample means of the endogenous variables and the number of available observations are depicted in the bottom rows of the tables. The explanatory variables refer to the preceding year. The first rows contain the results for the indicators of the demand situation, the other explanatory variables are related to market structure and cost and appropriability conditions.

<table>
<thead>
<tr>
<th>TABLE III Product and Process Innovations.</th>
</tr>
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<tbody>
<tr>
<td><strong>Innovation implemented</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Sales</strong></td>
</tr>
<tr>
<td><strong>Utilization</strong></td>
</tr>
<tr>
<td><strong>Product</strong></td>
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<tr>
<td>Product_t</td>
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<tr>
<td>1</td>
</tr>
<tr>
<td>Process</td>
</tr>
<tr>
<td>No innovation</td>
</tr>
<tr>
<td>All firms</td>
</tr>
</tbody>
</table>

Product: product innovation implemented.
Process: process innovation implemented.
No innovation: neither product nor process innovation implemented.
Δln s: growth rate of nominal sales.
U: capacity utilization rate.
The estimation results firstly reveal that a high capacity utilization rate in the preceding year $U$ increases the probability of implementing an innovation. Capacity utilization also exhibits the expected positive and significant effect on innovation activities, innovation expenditures and investment. This confirms the assumptions of the autocorrelation of demand shocks and a slow adjustment of capacities with respect to demand. It can also be interpreted as a second hint for a complementarity of innovations and investment. Capacity utilization (and demand expectations) should be the most important determinant of investment, and a strong effect on innovations implies that firms implement innovations when they invest. This argumentation is enhanced by the larger effect of capacity utilization on process innovations (see Tab. V). The respective coefficient exhibits nearly twice the value as those of product innovations; here a stronger complementarity was expected. The results also reveal that capacity constraints, i.e. a capacity utilization rate above 95 percent, reduces innovations. This indicates some importance of arguments of intertemporal substitution for innovation behaviour. A corresponding intertemporal substitution effect on investment is not revealed, and the effect on process innovations is not significant.

The medium-run demand expectations exhibit a very strong effect, growing markets favour innovations and investment. Note that the basic model of capacity adjustment implies a linear homogeneity of capacities and expected demand. Innovations are related to the development of demand through the complementarity with capital investment. A strong effect is revealed
for those firms that expect a growing market $Z^+$, the expectation of a shrinking market $Z^-$ affects mainly product innovations and investments in structures. The quantitative effect is remarkable. Firms that expect a growing market exhibit an about 10 percentage points higher probability to innovate and about 1 percentage point higher innovation and investment rates. The models for investment and innovation rates are estimated by Tobit, i.e. the coefficients reflect effects on the latent variables, not on the means of the variables. The probability effect in the probit models is evaluated at the mean of the variables.

A final cyclical indicator are price increases $\Delta_p$. Realized price increases in the past indicate a short-run excess demand situation on the goods market and consequently large cash flows; they might also indicate a less competitive situation on the product market. The estimation results reveal a significantly positive effect only on the probability of the implementation of innovations, not on innovation expenditures and investment. In addition, the effect on process innovations is smaller. The results indicate that cash flow affects mainly the timing of the introduction of a new product, innovation activities and investment do not depend that much on retained profits from a short-run excess demand situation on the goods market.

These results reveal that innovation behaviour and investment depend on the same set of cyclical variables, albeit with a different weighting for each. The medium-run demand

<table>
<thead>
<tr>
<th>TABLE V Disaggregate Innovation and Investment.</th>
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<tbody>
<tr>
<td><strong>Innovation</strong></td>
</tr>
<tr>
<td>Product</td>
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<tr>
<td>----------</td>
</tr>
<tr>
<td>$U$</td>
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<tr>
<td>(4.5)</td>
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<tr>
<td>$U &gt; 0.95$</td>
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<tr>
<td>(-3.0)</td>
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<tr>
<td>$Z^+$</td>
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<tr>
<td>(13.5)</td>
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<tr>
<td>$Z^-$</td>
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<tr>
<td>(-2.0)</td>
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<tr>
<td>$\Delta_p$</td>
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<tr>
<td>(5.6)</td>
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<tr>
<td>$\sigma_p$</td>
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<tr>
<td>(-8.8)</td>
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<tr>
<td>$\sigma_{\gamma D}$</td>
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<tr>
<td>(4.7)</td>
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<tr>
<td>Export</td>
</tr>
<tr>
<td>(21.2)</td>
</tr>
<tr>
<td>$50 \leq \tilde{I} &lt; 100$</td>
</tr>
<tr>
<td>(8.6)</td>
</tr>
<tr>
<td>$100 \leq \tilde{I} &lt; 200$</td>
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<tr>
<td>(15.9)</td>
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<tr>
<td>$200 \leq \tilde{I} &lt; 500$</td>
</tr>
<tr>
<td>(20.2)</td>
</tr>
<tr>
<td>$500 \leq \tilde{I} &lt; 1000$</td>
</tr>
<tr>
<td>(19.9)</td>
</tr>
<tr>
<td>$1000 \leq \tilde{I}$</td>
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<tr>
<td>(24.5)</td>
</tr>
<tr>
<td>Divers</td>
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<tr>
<td>Mean</td>
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<tr>
<td>Obs</td>
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<tr>
<td>Probit</td>
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<tr>
<td>Tobit</td>
</tr>
</tbody>
</table>

Coefficients of time dummies not reported. $t$-statistic in parantheses. Unbalanced panel.

25A stagnating market is the reference case.
26The models for investment and innovation rates are estimated by Tobit, i.e. the coefficients reflect effects on the latent variables, not on the means of the variables. The probability effect in the probit models is evaluated at the mean of the variables.
expectations affect the implementation of innovations, innovation activities and investment equally. Capacity utilization affects mainly capital investment and process innovations. Price increases in the past affect only the timing of the implementation of innovations. The results together imply that excess demand in the short run promotes innovations and therefore affects long-run growth. The complementarity of innovations and investment, the effect of cash flows on the financing conditions, and the expectation of a growing markets outweigh the effect of lower opportunity costs in recessions and intertemporal substitution.

Since price adjustments are also related to the competitive situation on the market, the results hint towards positive effects of market power on innovations. This interpretation is confirmed by the results of the second indicator of the competitive situation on the market. Low competition on the market favours quantity adjustment against price adjustments. Therefore, frequent price changes indicate strong competition on the product market. Market power, in turn, permits an easier finance of risky innovation projects out of cash flows and retained profits. The estimation results reveal that a large frequency of price changes $\sigma_p$ reduces innovations, especially product innovations,$^{27}$ a corresponding effect on investment is not found.$^{28}$ Market power enhances innovations but not investment. The results indicate that the effect of market power on the capability to introduce innovations is quantitatively more important than the effect on the incentives to innovate.

Quite different results for innovations and investment are revealed for demand uncertainty $\sigma_{YD}$. The relative frequency of demand changes in the past exhibits a positive effect on innovations, but a negative effect on investment. The negative effect on investment can be interpreted within the theoretical model as the effect on average costs which are higher in case of high demand uncertainty and consequently low average capacity utilization. The positive effect of demand uncertainty on innovations might be interpreted as an additional effect of market power. It could also be interpreted as a reaction of firms to introduce (product) innovations to reduce demand uncertainty.

Very different results for innovation behaviour and investment are revealed for export activities. Exporters exhibit a higher probability to innovate and higher innovation rates, but their investment rates are lower. The coefficients are highly significant and quantitatively large. Exporters exhibit about 2 percentage points higher latent innovation rates and 1 percentage point lower investment rates, ceteris paribus. The theoretical interpretation of this effect in not clear. It might indicate spillovers from foreign markets which affect the costs of innovations and technological opportunity.$^{29}$ It could also stem from a higher inventive capability which affects innovation behaviour and exports. Note the very strong effect of export activities on product innovations. One interpretation is that firms acting on international markets have more incentives to engage in quality competition. The lower investment rates of exporters could reflect the stronger competition on the world market which forces firms to a careful investment policy and/or more investment in foreign countries.

A final indicator of the competitive situation on the market is firm size $I$. Firm size exhibits a very strong and highly significant positive effect on innovations. This effect is equally strong for the probability of implementing product and process innovations and innovation activities, i.e. firm size hardly affects the composition of innovative activities. Note that the positive effect on the probability to innovate does not imply that large firms innovate

$^{27}$Note that this effect looses significance with the introduction of sectoral dummies. The frequency of price changes is highly correlated within the sector.

$^{28}$The larger effect of market power on product innovations, as compared with process innovations, is consistent with the argument that price increases for new products imply a smaller effect on market shares on monopolistic markets.

$^{29}$This would confirm the finding of intra-sectoral across-border spillovers and productivity convergence in Smolny (1999).
more per unit of sales; it also depicts the simple scale argument that in large firms, the probability of at least one innovation is higher. However, significant and quantitatively strong firm-size effects are also revealed for innovation rates: Large firm with more that 1000 employees spend more than 5 percentage points more for innovations than small firms with less that 50 employees, the reference case. The coefficients depict a clear positive relation of firm size and innovation rates. Investment rates, in contrast, are less affected by firm size. Small firms with less than 100 employees exhibit lower investment rates, but the difference of medium-size and large firms is small. The results indicate that the fixed cost argument is much more important for innovation behaviour as compared with investment. Finally, the positive effect on the probability of innovative activities and the about 1 percentage point higher innovation rates of diversified firms indicate positive spillovers of innovation activities for different products and/or an easier financing of innovation expenditures in diversified firms.

Taken together, the estimation results indicate that market power enhances innovations. Investment rates, in contrast, are larger for firms which operate on competitive markets. In addition, the probability of innovation projects and innovation rates increase with firm size. The corresponding effect on investment is smaller. Scale economies are more important for innovations as compared with investment.

4 CONCLUSIONS

Innovations increase the quality of goods and reduce the input requirement. Innovative firms are more successful and can achieve a temporary monopolistic situation on the product market. On the other hand, innovations depend on market power and on the demand situation of the firm. In this paper, estimates of the determinants of innovation behaviour and investment are presented. The microeconometric estimates are based on a theoretical framework with demand uncertainty, capacity constraints and monopolistic competition on the product market. The assumption of a delayed adjustment of innovations and investment under uncertainty of demand permits to discuss business cycle induced effects consistently within the framework of the theoretical model. The complementarity of innovations and investment emphasizes the interrelation of the investment and the innovation decision. The data base for the empirical investigation is a large panel of micro data for West-German manufacturing firms.

The empirical results firstly reveal strong positive effects for different demand indicators on innovation behaviour and investment. Demand shocks affect prices and output in the short run, and affect the financing conditions for innovations and investment in the long run. Excess demand in the short run promotes investment which enhances innovations, and innovations are the source of long-run advances in technology and productivity growth. This implies that short-run demand disturbances and the business cycle affect long-run growth. Firm size and market power also promote innovations. Market power affects innovation behaviour through effects on the financing conditions, and firm size is important in case of scale economies associated with innovations. An indicator of the competitive situation on the market is derived from the price-setting behaviour of the firms. A remarkable empirical result are the higher innovation rates of exporters. Investment rates of exporters, in contrast,

30 The estimates do not reveal a significant difference of the probability to implement an innovation in diversified firms. Note that the coefficient of the diversification dummy becomes significantly negative, if firm size is specified as the number of employees of the whole firm. The sample for investment excludes the diversified firms, therefore this variable is left out here.
are lower. Finally, investment rates are larger on competitive markets, and the firm-size effect is small.

Endogenous innovations, spillovers of technology and effects of innovations on competition are important concepts in endogenous growth models. From a theoretical perspective, they permit to understand technological change as endogenously determined by the profit maximizing behaviour of competing firms within the economic system. Innovations increase knowledge capital which increases the productivity of labour and physical capital. From a welfare economic perspective, innovations are the major source of the enormous income increases achieved in the past fifty years. Spillovers associated with innovations deserve attention since they indicate an inefficiency of decentralized market systems. If knowledge is distributed for free, as spillover models suggest, firms have too low incentive to engage in innovative activities. This enhances the interest into further empirical investigations of the determinants of innovation behaviour and the impact of innovations on productivity and competition.

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