Discussion Paper No. 04-85

The Link Between Firms' Innovation Decision and the Business Cycle: An Empirical Analysis

Diana Heger

ZEW
Zentrum für Europäische Wirtschaftsforschung GmbH
Centre for European Economic Research

Discussion Paper No. 04-85

The Link Between Firms' Innovation Decision and the Business Cycle: An Empirical Analysis

Diana Heger

Non-Technical Summary

Business cycle fluctuations have an important impact on entrepreneurial decisions. Whether they also influence the innovation decision, is investigated in this paper. Innovation activities are often referred to be almost independent of fluctuations of the business cycle. Several reasons can substantiate this: First, the duration of an innovation project often exceeds the duration of a business cycle phase. Second, firms may want to smooth their innovation expenditures and therefore try to continuously produce innovation output. Finally, innovation expenditures are often regarded as investments with sunk-cost characteristics and high adjustment costs. Therefore the question arises whether innovation activities really follow a smooth path or exhibit a cyclical pattern over time.

Different explanations for a link between innovation and economic activity can be found in the literature. Schumpeter (1939) states that science and technology (innovations) influence entrepreneurial activity and consequently the business cycle. This approach is known as supply-push. In contrast, Schmookler's (1966) hypothesis states that innovation crucially depends on market demand. According to this demand-pull approach, the patterns in the innovation activities may respond pro- and counter-cyclically to fluctuations in the business cycle.

This paper tests empirically whether the entrepreneurial decision to innovate is influenced by the business cycle. This dynamic economic process is modelled via first-order Markov chains. By this means the probability to switch from being not innovative to being innovative or vice versa is modelled. It is assumed that these probabilities are influenced by business cycle indicators, market structure and firms characteristics.

The results suggest that there are both pro- and counter-cyclical patterns in firms' innovation activities. On the one hand the probability for a non-innovative firm to start to innovate is dependent on fluctuations in economic activity only for SMEs, so that in this case small and medium-sized enterprises (SME) seem to be more sensitive than bigger firms. According to this result they tend to react counter-cyclically. Moreover, the probability for an innovative firm to stop innovating depends on fluctuations of the business cycle. But the effect is ambiguous because pro-cyclical as well as counter-cyclical patterns emerge.

The Link Between Firms' Innovation Decision and the Business Cycle: An Empirical Analysis

—

Diana Heger[1]

Abstract

The sensitivity of innovation activities with respect to the business cycle is often assumed to be small. In this paper the hypothesis on cyclical dependence of innovation activities is tested for firms in the German manufacturing, and additionally for SMEs. To this end firms' innovation decisions are considered. The decision to innovate in one period is modelled via a first-order Markov chain approach. The results suggest that the patterns in innovative behavior are linked to the business cycle.

Keywords: Innovation, Business Cycle, Panel Model, Markov Chains,

JEL-Classification: C23, C25, D21, L6, O31

Address: Centre for European Economic Research (ZEW)
Department of Industrial Economics
and International Management
P.O.Box 10 34 43
68304 Mannheim
Germany
Phone: +49/621/1235-382
Fax: +49/621/1235-170
E-Mail: heger@zew.de

[1]I am indebted to Dirk Czarnitzki, Andreas Fier, Helmut Fryges, Alfonso Gambardella, Max Keilbach, Kornelius Kraft, Georg Licht, Bettina Peters, Christian Rammer and Gerald Silverberg for their helpful comments and suggestions.

1 Introduction

Business cycle fluctuations have an important impact on entrepreneurial decisions. Firms react to them in the short run, e.g. by adjusting their investments to changes in their environment. In this paper a specific entrepreneurial decision is highlighted: the innovation decision. In an innovation process research and development (R&D) activities serves as input and innovation can be viewed as the output. R&D activities can also be interpreted as investment decisions with a long-term capital commitment so that adjustments cannot easily be made and fluctuations are assumed to be deviations from the mean. It is suspected that there also is a short-term component in R&D activities that is linked to cyclical patterns in economic activity. Indeed, following the worldwide recession at the beginning of the 1990s, a decline in R&D expenditures took place in most OECD countries, whereas in the precedent periods they had increased more or less steadily, even during the downward trend in economic activity in the 1980s. In this paper innovation activities are looked at. Generally, it is expected that business cycle does not have a strong influence on innovation activities since the duration of innovation projects often exceeds the duration of a business cycle. This is also due to the fact that firms may postpone the launch of new products if the economic situation is not according to their desire, i.e. the timing of R&D and innovation projects may fall apart.

The ways in which fluctuations in the business cycle and patterns in innovation activities are linked are a matter of discussion. Schumpeter (1939) states that innovations are not driven by the patterns of economic activity but that science and technology influence entrepreneurial activity and consequently the business cycle. This point of view is referred to as supply-push. According to Schmookler (1966), innovations depend crucially on the market demand (i.e., innovation activities tend to follow fluctuations in economic activity). This approach is called the demand-pull approach. Concerning this point of view, patterns in innovation activities can reflect the business cycle pro- and counter-cyclically. This paper relies on Schmookler's approach and investigates whether fluctuations in the business cycle influence innovation decisions via market demand.

The effect of cyclical fluctuations on innovation decisions is tested empirically for German manufacturing between 1993 and 2000. The analysis is based on the Mannheim Innovation Panel (MIP), which provides firm-level data on innovation behavior. To describe the fluctuations in economic activity at the sectoral level, data from the Business Climate Survey performed by the Institute for Economic Research (Ifo) in Munich was merged. In the relevant period of time fluctuations in the business cycle occurred. In 1992, one year later than the US economy, Germany experienced a decline in economic activity, which in 1993 resulted in the worst recession since World War II. Up to the year 1999 the economy grew at moderate rates between 0.8% (1996) and 2.4% (1994). Only in 2000 did the growth rate return to a higher level of 3%. Since 2001 Germany's economy has exhibited a stagnation[2].

The econometric model focuses on firms' decisions to innovate. To model the entrepreneurial decision process transition probabilities are introduced to describe the change in the innovative state of a firm. These transition probabilities rely on a binary variable indicating the innovative state of a firm and are modelled as first-order Markov chains, a powerful instrument used to describe dynamic economic processes. The transition probabilities are supposed to take a logistic form and are estimated by two separate logit models. The first includes all observations of non-innovative firms in period *t-1* and estimates the probability that they will begin to innovate. The second relies on all observations of innovative firms in *t-1* and estimates the probability that they will stop innovating. In addition to business cycle indicators, variables representing input price development, market structure and firm characteristics are included in the regression. The model is estimated for all firms in the sample and for the subset of small and medium-sized enterprises (SMEs).

The paper starts with an overview of the literature that considers the link between innovation and economic activity. The third section describes the data. The fourth section summarizes the econometric model. The results are presented in section 5 and section 6 concludes.

2 Literature review

First the link between innovation and R&D is to be stressed. Research and product or process development can be interpreted as input factors for the innovation process. The output are innovations, i.e. new products launched to the market. R&D and innovation fall temporally apart since innovations involve R&D and the launch of new products and timing is therefore subject to strategic decision making. Brockhoff (1997) consider this innovation process to be linear.

According to Rammer (2003) R&D expenditures accounted for 55 percent of innovation expenditures in 2000 and, taking new studies into account, tend to increase. The 'innovation process' R&D expenditures exhibit sunk cost characteristics because they mainly consist of labor costs, which are wages and costs of establishing firm-specific human capital[3]. Furthermore, adjustment costs involved in expanding R&D activities are particularly high. R&D expenditures thus should proceed according to a smooth time path and should exhibit almost no dependencies with respect to economic activity. Considering the close relation between innovation and R&D activities, innovation expenditures are expected

[2]The economic growth has been 0.8% in 2001, 0.2% in 2002 and -0.1% in 2003.

[3]Wages account for over 63 percent of the R&D expenditures (Stifterverband, 2004) and are sunk costs.

to be almost constant over time and should persist for some periods. Another argument that supports the assumption of more or less constant innovation expenditures are that the duration of innovation projects exceeds the duration of the business cycle. Reasons for this are that they consist mainly of sunk costs and are considered to be long-term investments. Furthermore, the decision when to launch a new product is made when the conditions are as desired.

Instead of being constant over time R&D expenditures show a certain pattern. Particularly at the beginning of the 1990s they declined following the worldwide recession. By which factors are these patterns driven? This section shows theoretical considerations and empirical assessments of two different explanations for the link between innovation activities and the business cycle: the so-called demand-pull and the supply(technology)-push approach.

Schumpeter can be counted among the advocates of the technology-push approach. He finds that a recession can be brought to an end by structural innovations that offer new opportunities for economic activity (Schumpeter, 1912). He also states that innovations are not driven by the patterns of economic activity but that science and technology influence entrepreneurial activity and consequently the business cycle (Schumpeter, 1939). Kleinknecht (1987) approves Schumpeter's hypothesis that radical innovations follow an uneven distribution over time. Kleinknecht (1990) reviewed the theory of the Schumpeterian waves of innovations and models investments in capacity as a positive function of radical innovations, the number and impact of subsequent innovations, and the degree of diffusion.

Metcalfe (1981) links innovation diffusion theory with theories of industrial growth. He models the diffusion of innovation taking into account the role of suppliers and imitators of innovation. Hence, adoption decisions are influenced by the increase in profitability offered by an invention to its supplier as a result of further incremental innovations and increases in capacity which reduce the costs of producing the innovation. Abernathy and Utterback (1975) develop a life cycle model that relates the changing pattern of innovation to the increasing maturity of an industry. The conclusion is that the link of radical and subsequent innovations leads to diminishing returns on innovation towards the later stages of the life cycle.

Jovanovic and Lach (1997) analyze the relationship between innovation and economic activity empirically. They report that product innovations can explain fluctuations at lower frequencies but underestimate fluctuations at higher frequencies. This at least partly supports the supply-push approach.

Schmookler is considered one of the main proponents of the demand-pull approach. He states in his work 'Invention and Economic Growth' (1966) that innovation depends crucially on market demand.[4] Shleifer (1986) affirms that there are complementarities between aggregate demand and growth. He assigns

[4]See Scherer (1982) for a critical review.

this issue to aggregate demand externalities in the implementation of innovations.

The demand-pull approach allows for both pro- and counter-cyclical patterns in innovation decisions to account for fluctuations in economic activity. One aspect of the counter-cyclical approach is the opportunity-cost view. Aghion and Saint-Paul (1998) present a two-state Markov model[5]. As a result, the opportunity costs of innovation decrease in recessions because they are borne during the recession, whereas the corresponding benefits are spread out over time. Consequently, it seems rational to invest in innovations during a recession.[6] Another theory is proposed by Kleinknecht and Verspagen (1990). They state that launching innovations evokes multiplier and accelerator effects for market demand.

Brockhoff and Pearson (1998) observe that R&D budgets are often cut as a consequence of a recession, which accounts for a procyclical reaction to changes in market demand. One possible explanation is that recessions may result in structural changes in a firm's activity and consequently in the level and composition of its R&D budget. Other arguments for pro-cyclical patterns are provided, inter alia, by Himmelberg and Petersen (1994). They show that cash flow has a strong influence on R&D expenditures. Since cash flow is generated by the actual activity of the firm, it responds pro-cyclically to variations in economic activity. Furthermore, markets have a limited capacity for absorbing new products, which is shown in a theoretical model by Judd (1985). Therefore the introduction of a new product is most probable when market conditions are favorable.

Kleinknecht and Verspagen (1990) argue that demand-pull and technology-push effects might be complementary rather than mutually exclusive. This point of view is also supported, even strengthened, by neo-Schumpeterian literature. It is suggested that the relative weight of "demand-pull" and "supply-push" can vary with the industry stage and with the type of innovation. Technology-push is considered to be more important for innovative breakthroughs, while demand-pull seems to be more important for subsequent innovations.

The empirical investigations in this field are numerous. Saint-Paul (1993) applies a semi-structural vector-regressive (VAR) methodology. He states that there is little evidence of any pro- or counter-cyclical pattern of R&D particularly if the distinction between demand and supply shocks is made. Despite Saint-Paul's conclusion, other studies find evidence supporting the demand-pull approach. Geroski and Walters (1995) employ count data on innovations and patents to investigate whether changes in demand cause fluctuations in innovations and patents. They conclude that changes in both innovation and patenting depend on demand and tend to be pro-cyclical. Guellec and Ionnidis (1999) analyze the effect of several business cycle indicators at the level of R&D expenditure in sev-

[5]They assume that innovations tend to be counter-cyclical, but that their overall effect depends on whether entry costs are fully recouped upon exit.

[6]Other OC-approaches are provided by Davis and Haltiwanger (1990), Hall (1991), Gali and Hammour (1991) and Caballero and Hammour (1992).

eral countries by means of aggregate sectoral data. They find that in the case of Germany heavy macroeconomic shocks (e.g., those caused by reunification) had a detrimental effect on all forms of investment including R&D[7]. Smolny (2003) investigates the relationship between innovation behavior and business cycle indicators. He shows that a boom has a positive impact on the level of innovation expenditures as well as on the probability to innovate. Brouwer and Kleinknecht (1999) analyze firm-level R&D and find evidence of the important role of demand growth in varying R&D efforts. They state that this adds to the recent evidence that innovative output depends on demand. Le Bas (2000) estimates the effects on 'demand/R&D expenditures elasticities' with error correction models[8] for seven OECD countries. He confirms a short-term effect of demand on R&D expenditures. The long-term effect turns out to be rather weak. Geroski and Machin (1993) show that innovating firms are less sensitive to cyclical shocks than non-innovating firms. This finding may be founded in a more flexible and adaptable behavior of innovators to new technological developments. They therefore conclude that "most firms, innovative or not, can prosper in a buoyant market, but only a few of the more innovative ones can continue to do so when the going gets tough."

Walsh (1984) analyzes the sensitivity of the chemical sector with respect to fluctuations in the business cycle and finds evidence for the neo-Schumpeterians approach. She states that "there is evidence to support both Schumpeter and Schmookler in the origins of the chemical sectors; in the secondary rapid growth phase there is evidence that market growth in the new products, resulting from the radical innovations, stimulated the swarming secondary innovations. The balance of 'supply' and 'demand' forces changed over the industry life cycles. In the mature phase of the industry sectors, with worldwide diffusion of innovation, the scale-up, the process innovations and more and more secondary product innovations in established product groups resulted from self-reinforcing upsurges in demand and secondary innovation. Finally, in all the sectors, various retardation factors have begun to slow down the growth rates and the rates of patenting, publication and technical advance."

The hypothesis tested in this paper relies on Schmookler's demand-pull approach. Therefore we investigate whether there are cyclical patterns in innovation decisions caused by fluctuations in economic activities transmitted by market demand. Since it is more likely that SMEs are more vulnerable to business cycle fluctuations than big firms, we estimate the same model separately for SMEs and expect that they are more sensitive to fluctuations in innovative activities. The stronger vulnerability of SMEs derives from the fact that normally they are

[7] Hall and Mairesse (1991) also find a pro-cyclical pattern in R&D expenditures for French manufacturing.

[8] Investment in R&D is described in terms of dynamic mechanisms which capture short- and long-term effects.

active in one or only few markets, so that no internal balancing of business cycles in different product markets is possible. Furthermore, they face stronger financial constraints, a smaller degree of internationalization and different absorption abilities.

3 Data and descriptive considerations

The underlying data set is provided by a conjunction of the Mannheim Innovation Panel (MIP) conducted by the Centre for European Economic Research (ZEW) and the Business Climate Test of the Institute for Economic Research (Ifo). The MIP has provided annual firm-level information on innovative behavior in the German manufacturing between 1993 and 2000. Every four years the MIP is also the German contribution to the CIS, the European Community Innovation Survey. Thanks to Ifo's Business Cycle Survey data on economic activity at the industry level is available. The database used for the econometric analysis consists of 6,979 observations on firms in the manufacturing sector, 67% of which are SMEs.

The data set is restricted to firms with less than 1,000 employees because it is more likely that relatively small firms switch between being innovative and non-innovative. Moreover, we have also found this fact in the data set; larger firms are either innovative or not innovative, but do not switch for a long period of time. Furthermore, we estimate the model described in section 4 separately for SMEs defined as firms with less than 250 employees and with sales less than 40 million Euro (European Commission, 2003).

The dependent variable of the econometric model is the innovation behavior or more specifically the innovation decision. Since product and process innovators behave differently only product innovators are considered. In the data set there is a variable that indicates if a firm is a product innovator in a specified period of time. However, by using this variable a measurement problem arise: the variable only indicates whether there has been any product innovation within a three-year period. In order to genuinely measure a product innovation in a specific year we combine the product innovator variable with the innovation expenditures since they are measured annually. Thus, we get a dummy variable that indicates whether the firm in question has been a product innovator in the current and the two precedent years and whether it has innovation activities in the current year derived by positive innovation expenditures. In this way we try to genuinely measure if a firm is a product innovator in a certain period[9].

[9] With this methodology it is not possible to identify if a firm has really been a product innovator in the same period in which its innovation expenditures has been positive, since the variable product innovator observed for a three years period. But it can be assumed that this error negligible.

$$innovation_{it} = \begin{cases} 1 & \text{if product innovator and innovation expenditures}_{it} > 0 \\ 0 & \text{otherwise} \end{cases}$$

where firm *i=1,...,n* is observed in period *t=1,...,T*.

According to Table 1 almost 61 percent of the observations in the sample deal with innovators. To describe a firm's innovation decision, the innovation dummy variable is transformed into four indicator variables. These four variables indicate the transition from innovator to non-innovator or vice versa between two periods and thus represent firms' innovation decision. We thus arrive at indicators of firms that were not innovating and in the subsequent period choose either to innovate or remain a non-innovator. An innovative firm has to decide in each new interval whether or not to continue innovating. These four transitions are represented by four binary variables[10].

$$decision_{00} = \begin{cases} 1 & \text{if innovation}_{i,t-1} = 0 \text{ and innovation}_{it} = 0 \\ 0 & \text{otherwise} \end{cases}$$

$$decision_{01} = \begin{cases} 1 & \text{if innovation}_{i,t-1} = 0 \text{ and innovation}_{it} = 1 \\ 0 & \text{otherwise} \end{cases}$$

$$decision_{10} = \begin{cases} 1 & \text{if innovation}_{i,t-1} = 1 \text{ and innovation}_{it} = 0 \\ 0 & \text{otherwise} \end{cases}$$

$$decision_{11} = \begin{cases} 1 & \text{if innovation}_{i,t-1} = 1 \text{ and innovation}_{it} = 1 \\ 0 & \text{otherwise} \end{cases}$$

where the first index of the decision variable refers to the innovation state in period *t-1* and the second to the state in period *t*.[11] This variable definition leads to a Markov model with the aid of which transitions in behavior can be analyzed.

The aim of this paper is to investigate the effect of economic activity on the innovation decision. Besides economic activity there are other factors that can influence innovation activities which must be included in the regression to control for their potential influence on innovation decisions.

[10] Table 4 and Table 5 show the distribution of the four transition for all firms and for SMEs respectively.

[11] The 0 refers to innovation=0 and 1 refers to innovation=1. From this it follows that $decision_{01}$ indicates a non-innovative firm in t-1 deciding to innovate in t.

According to Schumpeter (1911, 1942) firm size and market structure are relevant for innovation activities. The bigger the firm the riskier its projects may be conducted; increased size also imparts easier access to alternative sources of financing like venture capital, thereby broadening expectations with respect to innovation activities. A high market power promotes firms' innovation activities. The effect of market power is ambiguous. Following Arrow (1962)'s argumentation high market power leads to a low inclination to innovate. According to Gilbert and Newbury (1982) high market power causes preemptive innovations and patenting in order for maintaining a monopoly position. Furthermore, factor prices, financing opportunities, product diversification and firm-specific capabilities influence innovation activities: factor prices and financing opportunities impede innovation whereas product diversification and firm-specific capabilities favor innovation. Finally, export intensity, endowment with human capital and assignment to a certain industry are added as factors explaining innovation activities (Gottschalk and Janz, 2003; Schasse, 1998).

Table 1 shows the descroptive statistics for the variables included in the regression.[12]

Table 1: Descriptive Statistics

variable	mean	std. dev.	min.	max.
innovation	0.607	0.488	0	1
exp. business develop.^{*a}	-0.029	0.200	-0.63	0.747
capacity^{*a}	0.831	0.039	0.719	0.949
lack of qualified labor^{*a}	0.025	0.029	0	0.14
real tariff salaries^{*b}	1.035	0.058	0.761	1.520
real interest rate^{*b}	0.087	0.034	-0.048	0.337
turnover growth	1.069	0.403	0.095	12.743
Herfindahl index^{*c}	0.045	0.064	0.003	0.642
market share	0.003	0.010	0	0.248
employees	167.726	199.151	5	1,000
human capital	0.108	0.108	0	1
Eastern Germany	0.338	0.473	0	1
export intensity	0.289	0.341	0	1
product life cycle	11.454	10.659	0.1	150
diversification	0.648	0.124	0.07	1
number of observations		6,979		

*measured on a sector level ^{a}for 62 product groups, ^{b}for 2-digit NACE and ^{c}for 3-digit NACE.

Factors reflecting economic activity

[12] Table 6 in Appendix C shows them for SMEs.

Indicators of economic activity

Fluctuations in economic activity are often represented by variation of GDP over a length of time. GDP is an aggregation of several economic factors that together account for the business cycle. In the regression economic activity at the sector level is represented by three indicators. They are taken from the Ifo's Business Climate Survey and are measured as indices. The variable *lack of qualified labor* shows the variation in the labor market for qualified personnel with respect to the previous period. It exhibits a high value in boom periods since the demand for the scarce input of qualified labor is high during such stages. It is measured by the share of firms that agree that the lack of qualified labor impedes their production. The variable *expected business development* represents the firms' expectations of future business development. It is an indicator of how well businesses are expected to perform in the subsequent six months in terms of amelioration, downturn or levelling off. *Capacity* represents the demand conditions in the product market, i.e., a high demand in the market gives rise to a high level of production, which in turn leads to high capacity utilization ratio. Therefore, high capacity utilization is normally observed in periods of high economic activity. This variable is measured by the industry-average percentage that firms state as their capacity utilization.

Cyclical variation in the costs of innovation and internal financing conditions

Even if there might be no direct effect of the business cycle on innovation activities, economic activity influences factors that are crucial for innovation via transmission mechanisms. Such transmission mechanisms are exemplified by internal financing conditions and funding via the capital market. Additionally, the situation in the labor market as it pertains to highly qualified individuals can account for a link between the business cycle and innovations. This link is established through the price (i.e., wages) of qualified labor. Taking this into account monthly tariff salaries and banks' debit interests at the sector level are included in real prices. *Real tariff salaries* and *real interest rate* control for price changes in the factor markets according to the business cycle. This price development in supply markets does not directly account for the business cycle; instead, it is a reaction to fluctuations in economic activity seeking to eventually level them out. Interest rates also account for the availability of external financing sources such as credits. They represent opportunity costs of innovation investment

As an indicator of internal financing conditions the real firm's *turnover growth* is used.

$$turnover\ growth_{it} = \frac{sales_{it} * price_{t-1}}{sales_{i,t-1} * price_t}$$

where firm i is observed in periods t and *t-1.* To account for the skewness of the distribution of turnover all related factors, also turnover growth, are included in log terms. One indirect effect of a downturn in economic activity increases tension concerning internal financing conditions. Therefore, turnover growth should be positive in boom periods. Table 1 shows that, on average, real turnover grew by 6.1 percent.

Factors influencing innovation activities

These factors explaining innovation activities have to be included in the regression function to control for effects on firms' innovation behavior that are not linked with business cycle fluctuations. If they were not included their effect on innovation behavior would be represented in part by the variables accounting for economic activity and the error term, giving rise to the problem of omitted variables. The factors described here may fluctuate but these fluctuations may not correspond to the business cycle.

Market structure

Market share and *Herfindahl index* are inserted as measures of the market structure which can exert influence on innovation behavior. Market share is based on a three-digit NACE level and is defined as

$$market\ share_{it} = \frac{sales_{it}}{\sum_{j=1}^{N^s} sales_{jt}}$$

where the firms $j=1,\dots,N^s$, including firm i, are active in sector s, at time t. This variable shows the relative weight of a firm in the market.

The Herfindahl index measures market concentration, the effect of which on innovation is not clear. In the related literature this effect is argued in the case of a monopoly. Arrow (1962) shows that a monopolist's incentive to innovate is lower compared to inventors with no market share due to the expected loss of the monopolist's current profits. Gilbert and Newbery (1982)'s model instead concludes that an incumbent monopolist tries to maintain its position through innovation and preemptive patenting. This setting resembles Baumol et al. (1986)'s definition of contestable markets in which the entry barriers are reflected by innovations. Czarnitzki and Kraft (2000) test empirically whether the incumbent or the challenger invests more in R&D. They state that the challenger invests more whereas the incumbent has no significantly higher R&D intensity.

Firm-specific characteristics

The number of *employees*[13] illustrates firm size, which controls for the effect of

[13]To account for the skewness of the distribution of firm employees this term is included in log terms.

Schumpeter's hypothesis that increased firm size implies an increased inclination to innovate. Furthermore, small and medium-sized enterprises are expected to adapt their innovation activities faster to changes in the economic activity because they are acting in a lower number of different product markets than larger firms. The average firm in this sample has 166 employees. There are several studies that show that the effect of firm size on innovation is not linear. For that reason the size should also enter as squared term. In this paper size is only a control so that it only enters linearly into the regression.

Endowment in *human capital* is also crucial for innovations and can account for the firms' absorption ability. This is described by the proportion of highly educated labor to all employees of a firm. The following expression, which is assumed to have a positive influence on innovations, represents this proportion:

$$human\ capital_{it} = \frac{skilled\ labor_{it}}{all\ employees_{it}}$$

where i represents one specific firm in a certain period of time t. The considered firms employ, on average, a work force of which nearly 11 percent is highly qualified (i.e., hold a university degree). Moreover, export is seen as one important pillar of the German economy and is included in the regression as *export intensity*.

$$export\ intensity_{it} = \frac{export_{it}}{sales_{it}}$$

Internationally operating firms are often more innovative than domestically operating ones in order to maintain or increase their international competitiveness. Therefore the export intensity also reflects the dependence of these business cycles. The proportion of exports in sales is almost 30 percent for the average firm.

Export intensity is included in the regression because it measures the foreign business cycle which is important for firms' international commitment. But inserting export intensity a substantial endogeneity problem arises: the export intensity is linked to the domestic business cycle. When the domestic business cycle is unfavorable for firms they tend to export more. The endogeneity emerge via the timing. There are several remedies to solve this problem. Export intensity enters as a lagged variable or export is included as a dummy variable accepting a substantial loss of information. We did the regression with both and decided to rely on export intensity since the results do not change significantly.

Bernard and Wagner (2001) give another reason why exporting firms may be more innovative. They state that export entry is associated to substantial sunk costs. The firms try to keep on exporting by strengthening their position in the international competition via innovation.

According to Gottschalk, Janz (2003) and Schasse (1998) product *diversification* also accounts for innovation activities. If a firms's product portfolio is highly diversified it is more likely to launch new or improved products and the dependence of business cycles in certain product markets is smaller. Product diversification can be regarded as risk diversification so that losses caused by the failure of one product may be compensated by the gains from other products of the portfolio. To approximate product diversification we include the proportion of the respective most important product's sales to total sales.

Finally, an indicator of firms situated in *Eastern Germany* is inserted because Eastern Germany still lags behind with respect to economic and innovative success. Hence, the effect of this indicator is assumed to be negative with respect to innovation. Approximately 34 percent of the observations represent Eastern German firms.

Sector-specific characteristics

Finally sectors' average *product life cycles* are inserted as a measure of how great the incentive to innovate is. If the product life cycle is long the incentive to innovate steadily is low (Beise and Stahl, 1998). The average product life cycle is almost twelve years. Industry dummies[14] are also included in the equation to capture technological opportunities and industry-specific appropriateness (Schasse, 1998).

4 The econometric model

The econometric specification enables us to model firms' innovation decisions. Markov chains are a powerful instrument used to model sequential decision making, and thus to study dynamic economic processes (Rust, 1994; Nguyen et al., 2000). Markov chains are defined as a sequence of random variables. They realize one of several possible states in one period, which depends crucially on transition probabilities and initial state.

Gouriéroux (2000) states that Markov chains are used in the context of panel data with qualitative dependent variables. The qualitative variable y can take j=*1,...,J* different values and is observed t=*0,...,T* times. This variable constitutes a Markov chain if y_t does not depend on previous values of y except through the intermediary effect of y_{t-1}. The variable y_t is said to be a first-order Markov chain if

$$Pr(y_t = j_t | y_{t-1} = j_{t-1}, ..., y_0 = j_0) = Pr(y_t = j_t | y_{t-1} = j_{t-1}) \quad \forall\ t, \mathrm{j}_t, \mathrm{j}_{t-1}, ..., j_0. \tag{1}$$

This means that the chosen state in any period only depends on the state of the previous period.

[14]The classification of the industry dummies can be found in Table 3 in Appendix A.

The switch-over from state j to j' is modelled via the so-called transition probabilities $P_{ijj'}(t)$[15] for an individual i at time t. These probabilities are functions of exogenous variables. For the sake of simplicity the transition probabilities are assumed to take logistic form

$$P_{ijj'}(t) = \frac{exp(x_{itjj'}\beta_{jj'})}{\sum\limits_{j'=1}^{J} exp(x_{itjj'}\beta_{jj'})}. \tag{2}$$

For identification the assumption $\beta_{j1} = 0$ is set. This results in

$$P_{ij1}(t) = \frac{1}{1 + \sum\limits_{l=2}^{J} exp(x_{itj}b_{jl})} \tag{3}$$

$$P_{ijj'}(t) = \frac{exp(x_{itj}b_{jj'})}{1 + \sum\limits_{l=2}^{J} exp(x_{itj}b_{jl})}. \tag{4}$$

All transition probabilities can be written in the so-called transition matrix, enabling specification of equations 3 and 4 can be specified as a multinomial logit for each row of the transition matrix.[16]

Cefis (2003) applies a second-order Markov chain approach as well[17], modelling

$$Pr(y_t = j_t | y_{t-1} = j_{t-1}, ..., y_0 = j_0) = Pr(y_t = j_t | y_{t-1} = j_{t-1}, y_{t-2} = j_{t-2}). \tag{5}$$

$$\forall\ t,\ j_t,\ j_{t-1}, ...,\ j_0.$$

The relation is implemented by transforming this second-order Markov process into a first-order process expanding the state space.[18] Combining this result with the previous remarks, the second-order Markov chain can be estimated via a multinomial logit model after having expanded the state space, allowing the model to be represented as a first-order Markov chain.

In this study the Markov chain approach based on Gouriéroux (2000) is applied to the four possible transitions between innovation and non-innovation, simplifying the multinomial logit to two separately estimated binary logit models. The first equation accounts for the decision of all non-innovative firms to innovate in the subsequent period or not, and the second for the decision of all innovative

[15] $P_{ijj'}(t)$describes the probability of individual i changing its state from j to j' during the transition from period *t-1* to period *t*.

[16] An application to internationalization strategies can be found in Fryges (2004).

[17] Cefis (2003) analyzes whether there is persistence in innovative activities using patent data.

[18] See Stokey and Lucas (1989) for proof.

firms to cease innovating. Since this study tries to identify any dependencies between innovation behavior and fluctuations in economic activity, the explanatory variables consist of business cycle indicators and control variables as described in section 3. In the context of this paper the first-order Markov chain approach is adequate since only the decision from one period to another is modelled - hence, we focus on the state alone.

5 Empirical results

The aim of this paper is to test empirically whether the innovation decision depends on economic activity and of its phases. This decision process is estimated by two separate equations, which are represented as first-order Markov chains for the dichotomous variable of *product innovation*.

All business cycle related variables are included in first differences[19] because it is assumed that the changes of these variables account more realistically for the decision process than the level of the precedent period. The other variables enter the regression as levels of the precedent period, they control for other aspects than the business cycle, that influence innovation activities. Lagging the control variables is motivated by the fact that we consider the innovation decision during the transition from *t-1* to *t*. Therefore, the decision is made taking into account the values adopted in *t-1*.

The results are represented by the regression coefficents and the marginal effects. Since a logit model is assumed to has an underlying latent model with a continuous dependent variable the coefficients are not fully interpretable because they corrspond to the latent model. Therefore, marginal effects are calculated which indicate the marginal impact of an explanatory variable on the probability that the dependent variable equals to one. the interpretation of the marginal effects is straight forward - a rise in the explanatory variable by a marginal unit leads to a X% increase (decrease) in the dependent variable if the marginal effect is positive (negative).

Table 2 presents the results of a logit regression pertaining to both the decision of a non-innovator to innovate in the subsequent period and the effects which cause an innovative firm to stop innovating for all firms in the sample and for SMEs.[20]

[19]The business cycle related variables are lack of qualified labor, expected business development, capacity, real tariff salaries and real interest rate. Turnover growth is already in first differences. The variables in first differences are indicated with Δ in the regression results.

[20]The results for all included variables can be found in Table 7 and 8 in Appendix D

Table 2: Regression Results

	non-innovator → innovator				**innovator → non-innovator**			
	Regression Coefficient		Marginal Effects		Regression Coefficient		Marginal Effects	
	all firms	SMEs	all firms	SMEs				
variable	Coef. (std. error)	Coef. (std. error)	Coef. (std. error)	Coef. (std. error)	Coef. (std. error)	Coef. (std. error)	Coef. (std. error)	Coef. (std. error)
Δ *exp. business develop.*	-0.297	-0.301	-0.045	-0.044	0.838***	0.800***	0.101***	0.112***
	(0.232)	(0.268)	(0.036)	(0.039)	(0.199)	(0.240)	(0.024)	(0.033)
Δ *capacity*	1.948	1.037	0.307	0.161	-4.730***	-4.845**	-0.648***	-0.720***
	(1.631)	(1.896)	(0.252)	(0.278)	(1.589)	(1.939)	(0.188)	(0.265)
Δ *lack of qualified labor*	-2.559	-3.752**	-0.397	-0.572**	-0.093	1.070	-0.013	0.159
	(1.674)	(1.896)	(0.259)	(0.277)	(1.325)	(1.603)	(0.158)	(0.221)
Δ *real tariff salaries*	2.396	0.130	0.531	0.028	-0.986	-0.238	-0.140	-0.011
	(2.622)	(3.082)	(0.406)	(0.452)	(2.483)	(3.095)	(0.297)	(0.427)
Δ *real interest rate*	-0.559	-1.282	-0.077	-0.178	2.736**	4.795***	0.387***	0.766***
	(1.343)	(1.588)	(0.208)	(0.233)	(1.199)	(1.506)	(0.143)	(0.206)
ln(turnover growth)	0.532**	0.710***	0.088**	0.109***	-0.521***	-0.497**	-0.062***	-0.066**
	(0.223)	(0.266)	(0.034)	0.039	(0.181)	(0.208)	(0.022)	(0.029)
Herfindahl index (t-1)	0.549	0.387	0.080	0.057	0.059	0.050	0.009	0.007
	(1.018)	(1.233)	(0.158)	(0.181)	(0.842)	(1.053)	(0.101)	(0.145)
market share (t-1)	6.457	-43.179	0.024	-0.012	-7.520	-67.755***	-0.028	-0.102
	(8.841)	(45.496)	(1.371)	(6.679)	(6.157)	(25.657)	(0.736)	(3.542)
ln(employees)	0.225***	0.366***	0.035***	0.054***	-0.521***	-0.290***	-0.038***	-0.040***
	(0.044)	(0.068)	(0.007)	(0.010)	(0.041)	(0.065)	(0.005)	(0.009)
human capital (t-1)	-0.513	0.294	-0.083	0.044	-1.654***	-1.876***	-0.192***	-0.266***
	(0.665)	(0.754)	(0.103)	(0.111)	(0.504)	(0.572)	(0.060)	(0.079)
eastern Germany	0.057	0.030	0.009	0.004	-0.335***	-0.373***	-0.039***	-0.051***
	(0.111)	(0.125)	(0.017)	(0.018)	(0.101)	(0.117)	(0.116)	(0.016)
export intensity (t-1)	0.290	0.309	0.047	0.044	-0.616***	-0.420*	-0.072***	-0.059*
	(0.188)	(0.221)	(0.029)	(0.032)	(0.208)	(0.239)	(0.025)	(0.033)
ln(product life cycle) (t-1)	-0.011	-0.007	-0.002	-0.001	0.070	0.067	0.008	0.009
	(0.054)	(0.068)	(0.008)	(0.010)	(0.061)	(0.070)	(0.007)	(0.010)
diversification (t-1)	-1.561***	-1.024**	-0.252***	-0.162**	0.751**	1.135**	0.097**	0.159**
	(0.389)	(0.511)	(0.060)	(0.075)	(0.377)	(0.485)	(0.045)	(0.067)
constant	0.265	0.405			-2.873***	-3.065***		
	(0.384)	(0.488)			(0.368)	(0.483)		
number of observations	2,592	2,039			4,387	2,618		
log-Likelihood	-1,256.478	-948.271			-1,714.331	-1,147.238		

***, **, * indicate significance at the 1%-, 5%- and 10%-level
Industry dummies are included.

Looking at the direct business cycle indicators - lack of qualified labor, expected business development and capacity - it can be assumed that, when a firm wants to start to innovate, business cycle only seems to be important for the innovation decision of SMEs. The lack of qualified labor has a significant negative effect on the probability that an SME start to innovate in the next period. The lack of qualified labor in a specific sector is high in boom periods so that the negative significance indicated that the increasing lack is an impediment for the probability of innovation. This can be explained by the importance of high qualified for the innovation process. This effect accounts for a counter-cyclical pattern of innovation activity. The result confirms our expectation that SMEs are more sensitive to fluctuations in the business cycle. The non-significance of the business cycle indicators for all firms means that the decision to start to innovate is independent of economic activity so that it can be concluded that an innovation is not postponed because of an unfavorable business cycle phase.

Regarding the decision to stop innovating is sensitive to business cycle fluctuations for both SMEs and all firms. However, the picture we get of cyclical dependencies of innovation decision is ambiguous. Looking at the direct business cycle indicators we get both pro- and counter-cyclical patterns in the innovation decision. The counter-cyclical pattern can be concluded by the positive effect of the expected business development variable. This effect can be explained by the opportunity cost approach. In boom periods firms tend to invest in production expansion to realize immediate gains instead of investing in innovation. Concerning capacity there is a pro-cyclical due to the negative significance of the coefficient. An increase in capacity utilization may result in higher sales and these sales may be put in innovation activities. The different effect of the expected business development and capacity may b counter-intuitive, but we have to take into account that the development expectation reflects the expected development in the six subsequent months and capacity reflects the actual business cycle situation.

The factor price for capital only has a significant influence on the probability to cease innovating. If interest rates increase by one percent the probability to stop innovating increases by 37.7%. This means that increasing interest rates rend the firms more willing to cease to innovating. This is due to the character of interest rates which accounts for opportunity costs generated by alternative investments.

Turnover growth is a crucial factor for the innovation decision, as it reflects the internal financing conditions. Its significance in both regressions means that firms more probably start to innovate (positive significance) when their internal financing conditions are favorable and stop innovating when they are unfavorable (negative significance).

The effect of the employees variable on the innovation probability is confirmative to Schumpeter's hypothesis that the bigger a firm the more probable it is innovative (positive significance for the probability to start to innovate) and keeps on innovating (negative significance to stop innovating). Moreover, an exporting firm has a higher probability to start to innovate and a lower one to stop innovating. This reinforces the assumption that the innovation probability of an internationally operating firm is dependent on the business cycle abroad as well as on the domestic one. The results suggest that the innovation probability of exporting firms tend to be sensitive as regards the foreign business cycle. If the domestic business cycle is less favorable with respect to the foreign one, i.e. the export intensity is increasing, the firm is more probably innovative (negative significance for the probability to stop innovating). Furthermore, the result supports the hypothesis that firms in international competition are more likely to innovate because they want to maintain or even strengthen their international competitive position.

Moreover, the diversification variable is constructed as the total sales proportion of the most important (with respect to sales) product. Its negative significance for the probability to start to innovate and its positive significance for the probability to cease innovating confirms the hypothesis that highly diversified firms are more innovative because a high sales proportion accounts for a low diversification.

Moreover, human capital[21] plays a crucial role in decisions to cease to innovating. If the proportion of skilled labor increases by one percent the probability to stop innovating lowers by 19.2 percent. This reflects the importance of human capital to innovation activities. If a firm has invested large amounts in human capital it would be less willing to stop innovating since investments in human capital are sunk costs. Looking at the marginal effect of export intensity, an increase of exports by one marginal unit with respect to constant sales decreases the probability of ceasing to innovating by nearly 10 percent (negative significance for the probability to cease innovating). This means that an exporting firms tends to keep on innovating in order to maintain its international competitiveness if the business cycle abroad seems to be more favorable than the domestic one.

The highly significant negative effect of the Eastern Germany dummy on the probability to stop innovating is contradictory to what we have expected. It may account for the fact that Eastern German firms may get special public subsidies for innovative projects to which Western German firms have no access. This subsidization is committed to continued innovation activities so that these firms may be more inclined to keep on innovating (Czarnitzki, 2001; Czarnitzki and Licht, 2004).

6 Conclusion

This paper aims to show whether there is any relation between fluctuations in

[21]Remember that human capital is measured at the firm-level whereas the lack of qualified labor is measured at the sector level.

economic activity and firms' innovation behavior. Schmookler (1966)'s approach pointing out that innovations depend crucially on market demand is the baseline of this paper. The data set used is a conjecture of the Mannheim Innovation Panel (MIP) and the Business Climate Survey if the Ifo. In order to investigate firm's innovation behavior, the innovation decision process is modelled via first-order Markov chains. The innovation decision is described by four binary variables: they indicate respectively firms starting to innovate, firms remaining non-innovative, firms that have stopped innovating and innovative firms continuing to innovating.

The specification of the regression function includes indicators for the business cycle as well as firm characteristics and market structure. Capacity constraints, lack of qualified labor and expected business development, all measured at the sector level, are inserted as direct indicators for the business cycle. Economic activities are also represented by factor prices namely real tariff salaries and real interest rate.

The estimation results show that both pro- and counter-cyclical patterns can be found in firms' innovation activities. Looking at the results of the probability to start to innovate, business cycle fluctuations only matter for SMEs which react counter-cyclically to the lack of qualified labor on the sector level. This accounts for the substantial importance of qualified labor for the innovation process. In turn, the probability of ceasing to innovating is influenced by fluctuations in the economic activity for all firms. Looking at the expected business development the firms react counter-cyclically to fluctuations, looking at the capacity utilization firms react pro-cyclically. The counter-cyclical reaction to changes in the expected business development can be explained by the fact that, in boom periods, firms may invest in production expansion to realize immediate gains instead of investing in innovation. This accounts for the opportunity cost approach. The pro-cyclical reaction to changes in capacity utilization may be due to higher sales if capacity utilization increases, which can be put into innovation activities.

Regarding the factor prices, only interest rates have a positive impact on the probability to cease innovating because they reflect the opportunity costs of alternative investments. The probability to start to innovate is not influenced by factor prices. Concerning the internal financing conditions (turnover growth) - which reflect business cycle at the firm level - they matter for the innovation decision. For innovative activities the internal financing conditions must be favorable. If they are not, firms' probability to be hesitant to start to innovate and to be more inclined to stop them increases.

Implications of the empirical results are that the willingness to innovate increases if the economic growth is expected to rise. Therefore an important means to increase the disposition to innovate is to fortify the business cycle by encouraging domestic demand.

These results motivate for further research in the field of dependencies between business cycle fluctuations and innovation activities. In theory, business cycle is regarded to be independent of economic growth. According to the real-business-cycle (RBC) theory there is a link between these two phenomena. Prescott (1986) states that "defining the business-cycle phenomena as the recurrent fluctuations of output about trend and the co-movements among other aggregate time series. Fluctuations are by definition deviations from some slowly varying path." This is one limitation of this paper: the influence of business cycle fluctuations on innovation decisions is proven but its long-term implications are not considered. They can be stimulating or impedimentary. This link is beyond the scope of this paper and may be subject to further empirical assessment.

In this paper only the output of an innovation process is considered. So another challenging subject will be to consider the influence of business cycle fluctuations on the input factor of the innovation process: R&D. This may be interesting because the main difference between R&D and innovation is the timing. When launching a new product firms will first check whether the market conditions are favorable to their strategy.

Another interesting topic is the influence of business cycle on the impediments of innovation activities, particularly the impediments of financial constraints. One hypothesis is that financial constraints worsen in recessions and firms with good innovation projects may postpone or even abolish their innovation projects because the financial constraints weigh heavy.

References

Abernathy, W. and J. Utterback (1975), A Dynamic Model of Process and Product Innovation, *Omega 3*, 639-656.

Aghion, P. and G. Saint-Paul (1998), Virtues of Bad Times: Interaction Between Productivity Growth and Economic Fluctuations, *Macroeconomic Dynamics 2*, 322-344.

Arrow, K.J. (1962), Economic Welfare and the Allocation of Resources for Invention, in: Nelson, R. (eds.), *The Rate and Direction of Inventive Activity*, Princeton.

Baumol, W.J., J. Panzer and R.D. Willig (1986), *Contestable Markets and the Theory of Industrial Structure*, Harcourt Brace and Jovanovitch.

Beise, M. and H. Stahl (1998), *Public Research and Industrial Innovations in Germany*, ZEW Discussion Paper 98-37, Mannheim.

Bernard, A.B. and J. Wagner (2001), Export Entry an exit by German Firms, *Weltwirtschaftliches Archiv 137*, 105-123.

Brockhoff, K.K. (1997), *Forschung und Entwicklung*, Oldenbourg, Munich.

Brockhoff, K.K. and A.W. Pearson (1998), R&D Budgeting Reactions to a Recession, *Management International Review 38*, 363-376.

Brouwer, E. and A. Kleinknecht (1999), Keynes-plus? Effective Demand and Changes in Firm-level R&D: An Empirical note, *Cambridge Journal of Economics 23*, 285-391.

Caballero, R. and M.L. Hammour (1992), *The Cleansing Effect of Recessions*, Columbia University Working Papers 572.

Cefis, E. (2003), Is There Persistence in Innovative Activities?, *International Journal of Industrial Organization 21*, 489-515.

Cyert, R.M., H.J. Davidson, G.L. Thompson (1962), Estimation of the Allowance for Doubtful Accounts by Markov Chains, *Management Science 8*, 287-309.

Czarnitzki, D. and K. Kraft (2000), *An Empirical Test of the Asymmetric Models on Innovative Activity: Who Invests More into R&D the Incumbent or the Challenger?*, ZEW Discussion Paper 00-10.

Czarnitzki, D. and G. Licht (2004), Die Rolle der Innovationsförderung im Aufholprozess Ostdeutschlands, in: D. Engel (Ed.), *Staatliche Förderung von Unternehmen: Ausgestaltung und Ergebnisse neuerer Evaluationen, Veröffentlichung des Round Table Mittelstandes Vol. 7*, Berlin, forthcoming.

Czarnitzki, D. (2001), Die Auswirkungen der Forschungs- und Technologiepolitik auf die Innovationsaktivitäten ostdeutscher Unternehmen, *Schmollers Jahrbuch - Zeitschrift für Wirtschafts- und Sozialwissenschaften (Journal of Applied Social Science Studies) 121(4)*, 539-560.

Davis, S. and J. Haltiwanger (1990), Job Creation, Job Destruction and Job Reallocation Over the Cycle, *NBER Macroeconomics Annual*.

European Commission (2003), Empfehlung 2003/361/EG zur KMU-Definition.

Fryges, H. (2004), *Stepping in and out the International Market: Internationalisation of Technology Oriented Firms in Germany and the UK*, ZEW Discussion Paper 04-65.

Gali, J. and M.L. Hammour (1991), *Long-Run Effects of Business Cycles*, Columbia University Working Papers 540.

Geroski, P.A. and S. Machin (1993), Innovation, Profitability and Growth over the Business Cycle, *Empirica 20*, 33-50.

Geroski, P.A., J. van Reenen, C.F. Walters (1997), How Persistently Do Firms Innovate?, *Research Policy 26*, 33-48.

Geroski P.A. and C.F. Walters (1995), Innovative Activity Over the Business Cycle, *The Economic Journal 105*, 916-928.

Gilbert, R.J. and D.M.G. Newbery (1982), Preemptive Patenting and the Persistence of Monopoly, *American Economic Review 72*, 514-526

Gottschalk, S. and N. Janz (2003), Bestimmungsfaktoren der Innovationstätigkeit, in: Janz, N. and G. Licht (eds.), *Innovationsforschung heut*, ZEW Wirtschaftsanalysen, Vol. 63, Baden-Baden.

Gouriéroux, C. (2000), *Econometrics of Qualitative Dependent Variables*, Cambridge University Press.

Guellec, D. and E. Ioannidis(1997), Causes of Fluctuations in R&D Expenditures: A Quantitative Analysis, *OECD Economic Studies 29*, 123-138.

Hall, R.E. (1991), Recessions as Reorganizations, *NBER Macroeconomic Annual*.

Hall, B. and J. Mairesse (1992), *Exploring the Relationship Between R&D and Productivity at the Firm Level in French Manufacturing*, Economics Working Papers 92-190, University of California at Berkeley.

Himmelberg, C. and B. Petersen (1994), R&D and Internal Finance: A Panel Study of Small Firms in High-Tech Industries, *Review of Economics and Statistics 76*, 38-51.

Jovanovic, B. and B. Petersen (1997), Product Innovation and the Business Cycle, *International Economic Review 38*, 3-22.

Judd, K.L. (1985), On the Performance of Patents, *Econometrica 53*, 567-585.

King, M. and M. Robson (1989), *Endogenous Growth and the Role of History*, NBER Working Papers 3151.

Kleinknecht, A. (1990), Are There Schumpeterian Waves of Innovations?, *Cambridge Journal of Economcs 14*, 81-92.

Kleinknecht, A. and B. Verspagen (1990), Demand and Innovation: Schmookler Re-Examined, *Research Policy 19*, 387-394.

Kleinknecht, A. (1987), *Innovation patterns in crisis and prosperity: Schumpeter's long cycle reconsidered*, Macmillan Press, London.

Le Bas, C. (2000), *Demand Growth as a Determinant of R&D: A Quantitative Study at the Sectoral Level*, Université Lyon 2.

Metcalfe, S. (1981), Impulse and Diffusion in the Study of Technical Change, *Futures 13*, 347-359.

Nguyen, V.P., U. Kaiser, F. Laisney (2000), *The Performance of German Firms in the Business-Related Service Sectors: A Dynamic Analysis*, ZEW Discussion Paper No. 00-32.

Prescott, E.C. (1986), Theory Ahead of Business-Cylce Measurement, *Carnegie-Rochester Conference Series on Public Policy 25*, 11-44.

Rammer, C. (2003), Innovationsverhalten der Unternehmen, *Studien zum deutschen Innovationssystem Nr. 12-2003*, Mannheim.

Rust, J. (1994), Structural Estimation of Markov Decision Processes, *Handbook of Econometrics 4*, 3082-3143.

Saint-Paul, G. (1993), Productivity Growth and the Structure of the Business Cycle, *European Economic Review 37*, 861-890.

Schasse, U. (1998), Bestimmungsgründe des Innovationsverhaltens von Industriebetrieben: Empirische Analysen auf der Basis von Betriebsdaten, in: Gerlach, K.; O. Hübler, W. Meyer (eds.), *Ökonomische analysen betrieblicher Strukturen und Entwicklungen: Das Hannoveraner Firmenpanel*, Frankfurt a.M.

Scherer, F.M. (1982), Demand-Pull and Technological Invention: Schmookler Revisted, *The Journal of Industrial Economics 30*, 225-237.

Schmookler, J. (1966), *Invention and Economic Growth*, Harvard University Press, Cambridge, MA.

Schumpeter, J.A. (1942), *Capitalism, Socialism and Democracy*, New York.

Schumpeter, J.A. (1939), *Business Cycles*, 2 Vols, McGraw-Hill, New York.

Schumpeter, J.A. (1912), *Theorie der wirtschaftlichen Entwicklung*, Duncker&Humblot, Leipzig.

Shleifer, A. (1986), Implementation Cycles, *Journal of Political Economy 94*, 1163-1190.

Smolny, W. (2003), Determinants of Innovation Behaviour and Investment: Estimates for West-German Manufacturing Firms, *Economics of Innovation and New Technology 12*, 425-447.

Stifterverband (2004), *FuE-Datenreport 2003/2004: Forschung und Entwickung in der Wirtschaft*, Bericht über die FuE-Erhebungen 2001 und 2002, Essen.

Stokey, N.L. and R.E. Lucas (1989), *Recursive Methods in Economic Dynamics*, Harvard University Press, Cambridge, MA.

Walsh, V. (1984), Invention and Innovation in the Chemical Industry: Demand-Pull or Discovery-Push?, *Research Policy 13*, 211-234.

Appendix A

Table 3: Cassification of Industry Dummies

Dummy	Description	NACE
industry dummy 1	Food, beverage and tobacco	15, 16
industry dummy 2	Textile, clothes and leather goods	17,18,19
industry dummy 3	Wood, paper, publishing, printing, furniture, jewellery, musical and sport instruments, toys and others	20, 21, 22, 36
industry dummy 4	Fuels, chemicals, rubber and plastic products	23, 24, 25
industry dummy 5	Non-metallic mineral products, basic metals and fabricated metals	26, 27, 28
industry dummy 6	Machinery and equipment	29
industry dummy 7	Office, data processing, electrical machinery and components, communication equipment and medical, optical instruments and watches	30, 31, 32, 33
industry dummy 8	Motor vehicles and components and other transports	34, 35

Appendix B

Table 4: Distribution of the four transitions

	innovative in t	*non-innovative in t*
innovative in t-1	3,716	671
non-innovative in t-1	523	2,069

Table 5: Distribution of the four transitions for SMEs

	innovative in t	*non-innovative in t*
innovative in t-1	2,139	479
non-innovative in t-1	381	1,658

Appendix C

Table 6: Descriptive Statistics for SMEs

variable	mean	std. dev.	min.	max.
innovation	0.541	0.498	0	1
lack of qualified labor	0.026	0.030	0	0.14
exp. business develop.	-0.035	0.197	-0.63	0.747
capacity	0.831	0.038	0.729	0.949
real tariff salaries	1.034	0.058	0.761	1.520
real interest rate	0.087	0.033	0.012	0.337
turnover growth	1.060	0.345	0.095	12.168
Herfindahl index	0.040	0.060	0.003	0.432
market share	0.001	0.004	0	0.248
employees	59.542	51.992	5	250
human capital	0.110	0.114	0	1
Eastern Germany	0.427	0.495	0	1
export intensity	0.241	0.339	0	1
product life cycle	11.451	10.929	0.1	150
diversification	0.673	0.116	0.12	1
number of observations		4,657		

Appendix D

Table 7: Regression Results for the probability non-innovator → innovator

	Regression Coefficient		Marginal Effects	
	all firms	SMEs	all firms	SMEs
variable	Coef. (std. error)	Coef. (std. error)	Coef. (std. error)	Coef. (std. error)
Δ *exp. business develop.*	-0.297	-0.301	-0.045	-0.044
	(0.232)	(0.268)	(0.036)	(0.039)
Δ *capacity*	1.948	1.037	0.307	0.161
	(1.631)	(1.896)	(0.252)	(0.278)
Δ *lack of qualified labor*	-2.559	-3.752**	-0.397	-0.572**
	(1.674)	(1.896)	(0.259)	(0.277)
Δ *real tariff salaries*	2.396	0.130	0.531	0.028
	(2.622)	(3.082)	(0.406)	(0.452)
Δ *real interest rate*	-0.559	-1.282	-0.077	-0.178
	(1.343)	(1.588)	(0.208)	(0.233)
ln(turnover growth)	0.532**	0.710***	0.088**	0.109***
	(0.223)	(0.266)	(0.034)	0.039
Herfindahl index (t-1)	0.549	0.387	0.080	0.057
	(1.018)	(1.233)	(0.158)	(0.181)
market share (t-1)	6.457	-43.179	0.024	-0.012
	(8.841)	(45.496)	(1.371)	(6.679)
ln(employees)	0.225***	0.366***	0.035***	0.054***
	(0.044)	(0.068)	(0.007)	(0.010)
human capital (t-1)	-0.513	0.294	-0.083	0.044
	(0.665)	(0.754)	(0.103)	(0.111)
eastern Germany	0.057	0.030	0.009	0.004
	(0.111)	(0.125)	(0.017)	(0.018)
export intensity (t-1)	0.290	0.309	0.047	0.044
	(0.188)	(0.221)	(0.029)	(0.032)
ln(product life cycle) (t-1)	-0.011	-0.007	-0.002	-0.001
	(0.054)	(0.068)	(0.008)	(0.010)
diversification (t-1)	-1.561***	-1.024**	-0.252***	-0.162**
	(0.389)	(0.511)	(0.060)	(0.075)
industry dummy 1	-0.008	0.002	-0.001	0.000
	(0.295)	(0.355)	(0.046)	(0.052)
industry dummy 2	-0.085	0.171	-0.013	0.026
	(0.312)	(0.366)	(0.046)	(0.058)
industry dummy 3	-0.206	-0.194	-0.031	-0.027
	(0.274)	(0.326)	(0.039)	(0.044)
industry dummy 4	-0.134	-0.076	-0.020	-0.011
	(0.273)	(0.325)	(0.040)	(0.046)
industry dummy 5	-0.126	-0.033	-0.019	-0.005
	(0.260)	(0.306)	(0.039)	(0.045)
industry dummy 6	0.277	0.167	0.045	0.025
	(0.278)	(0.323)	(0.048)	(0.051)
industry dummy 7	0.208	-0.024	0.034	0.004
	(0.281)	(0.338)	(0.048)	(0.050)
constant	0.265	0.405		
	(0.384)	(0.488)		
number of observations	2569	2028		
log-Likelihood	-1240.054	-945.104		

***, **, * indicate significance at the 1%-, 5%- and 10%-level

Table 8: Regression Results for the probability innovator → non-innovator

	Regression Coefficient		Marginal Effects	
	all firms	SMEs	all firms	SMEs
variable	Coef. (std. error)	Coef. (std. error)	Coef. (std. error)	Coef. (std. error)
Δ exp. business develop.	0.838***	0.800***	0.101***	0.112***
	(0.199)	(0.240)	(0.024)	(0.033)
Δ capacity	-4.730***	-4.845**	-0.648***	-0.720***
	(1.589)	(1.939)	(0.188)	(0.265)
Δ lack of qualified labor	-0.093	1.070	-0.013	0.159
	(1.325)	(1.603)	(0.158)	(0.221)
Δ real tariff salaries	-0.986	-0.238	-0.140	-0.011
	(2.483)	(3.095)	(0.297)	(0.427)
Δ real interest rate	2.736**	4.795***	0.387***	0.766***
	(1.199)	(1.506)	(0.143)	(0.206)
ln(turnover growth)	-0.521***	-0.497**	-0.062***	-0.066**
	(0.181)	(0.208)	(0.022)	(0.029)
Herfindahl index (t-1)	0.059	0.050	0.009	0.007
	(0.842)	(1.053)	(0.101)	(0.145)
market share (t-1)	-7.520	-67.755***	-0.028	-0.102
	(6.157)	(25.657)	(0.736)	(3.542)
ln(employees)	-0.521***	-0.290***	-0.038***	-0.040***
	(0.041)	(0.065)	(0.005)	(0.009)
human capital (t-1)	-1.654***	-1.876***	-0.192***	-0.266***
	(0.504)	(0.572)	(0.060)	(0.079)
eastern Germany	-0.335***	-0.373***	-0.039***	-0.051***
	(0.101)	(0.117)	(0.116)	(0.016)
export intensity (t-1)	-0.616***	-0.420*	-0.072***	-0.059*
	(0.208)	(0.239)	(0.025)	(0.033)
ln(product life cycle) (t-1)	0.070	0.067	0.008	0.009
	(0.061)	(0.070)	(0.007)	(0.010)
diversification (t-1)	0.751**	1.135**	0.097**	0.159**
	(0.377)	(0.485)	(0.045)	(0.067)
industry dummy 1	0.710**	0.630*	0.101**	0.100
	(0.282)	(0.364)	(0.046)	(0.065)
industry dummy 2	0.575**	0.463	0.079*	0.071
	(0.288)	(0.368)	(0.045)	(0.062)
industry dummy 3	0.710***	0.765**	0.100*	0.123**
	(0.266)	(0.343)	(0.043)	(0.063)
industry dummy 4	0.140	0.097	0.017	0.014
	(0.252)	(0.326)	(0.032)	(0.047)
industry dummy 5	0.490**	0.551*	0.064*	0.083
	(0.250)	(0.323)	(0.035)	(0.052)
industry dummy 6	-0.373	-0.188	-0.042	-0.025
	(0.261)	(0.330)	(0.027)	(0.043)
industry dummy 7	-0.339	-0.248	-0.038	-0.033
	(0.263)	(0.337)	(0.027)	(0.043)
constant	-2.873***	-3.065***		
	(0.368)	(0.483)		
number of observations	4369	2624		
log-Likelihood	-1695.164	-1140.394		

***, **, * indicate significance at the 1%-, 5%- and 10%-level