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Abstract

Aim of this study is to combine micro-aspects of firm behaviour with macro-aspects of business development and identify market conditions (for example, price competition) and firm characteristics (for example, type of R&D partners) that enable a firm to have a pro-cyclical, anti-cyclical or non-systematic R&D investment behaviour.

New elements of our analysis are: (a) the identification in our data of the above three main types of R&D behaviour with respect to the fluctuation of overall economic activity as measured by a standard composite indicator of the business conditions at industry level and (b) the investigation of a series of hypotheses as to innovation-relevant firm characteristics that underline the three different behaviour categories. The empirical results confirm to large extent our hypotheses and allow us to make profiles of the three types of R&D behaviour.

JEL Classification: O3

Key words: R&D; anti-cyclical behaviour; pro-cyclical behaviour

1. Introduction

There is some theoretical consent (see Bernanke and Gertler 1989, Barlevy 2007) and some empirical evidence (see Guellec and Ioannidis 1999, Rammer et al. 2004, Mairesse et al. 1999) that R&D investment expenditures of firms are pro-cyclical, i.e. they are increasing in the business upswing and they are decreasing in the business downturn. However, there is some anecdotical evidence that firms show an unsystematic or even anti-cyclical R&D investment behaviour. Hence, it is the aim of this study to combine micro-aspects of firm behaviour with macro-aspects of business development and identify market circumstances (e.g. competition) and firm characteristics (for example, type of R&D partners) that enable a firm to have an anti-cyclical or unsystematic R&D investment behaviour. Such investment behaviour is not only advantageous for the respective firm, it is also advantageous for the economy as a whole, since anti-cyclical investment behaviour clearly mitigates cyclical movement of the economy with all its negative aspects, like strong employment fluctuation.

In order to explain pro- or anti-cyclical R&D behaviour we have to take into account two diverging forces, i.e. demand aspects and the "opportunity cost" aspect. Since R&D investments are predominantly financed through the cash-flow of a firm, which is expected to fluctuate pro-cyclical with the demand, we would expect a pro-cyclical R&D investment behaviour as well. If the "opportunity cost" aspect prevails, we would expect the contrary; firms would make use of lower production costs in recessions and would intensify their R&D investments. As a consequence, this would not only make R&D activities cheaper, it would also increase the probability to market new products in the business upswing, when markets are in general more receptive for new products. Hence, our theoretical notions are around these two aspects and we have to figure out under which circumstances firms are able to follow the opportunity cost approach and when financial restrictions are likely to be dominant and firms have pro-cyclical R&D investment behaviour.

Based on firm-level panel data for manufacturing firms in Switzerland comprising 3 waves (2002, 2005, 2008) of the Swiss innovation survey and aggregated yearly data (3 digit-level) for the business cycles development in Switzerland (1999-2009) we could identify important firm characteristics and market conditions that are responsible for anti-cyclical R&D investment behaviour of firms. In sum, we could learn that firms can benefit from low opportunity costs through anti-cyclical R&D investments (compared to unsystematic R&D investment behaviour) if they have a relatively great sales share of R&D expenditures, if they have external R&D relationships, if they are not exposed to intensive price competition (e.g. working in international market niches), if they are operating in high-tech industries, and if they are relatively large. If we compare anti-cyclical firms with pro-cyclical firms at least three factors are important. Anti-cyclical firms have larger sales shares of R&D investments, they are less frequently cooperating with universities, and they are not exposed to intensive price competition. From a policy point of view the results indicate that innovation policy can contribute to mitigate the cyclical fluctuation of R&D investments through considering the just mentioned factors in their promotion activities. This would not only help firms make use of lower opportunity costs at recessions, it would also contribute to dampen the overall business fluctuation.

The paper is organized as follows. Section 2 summarizes the most important findings in the existing literature and introduces our theoretical framework and subsequent hypotheses. Section 3 discusses the data. Section 4 presents the main facts with respect to R&D and the business cycle development in Swiss manufacturing in the period 1999-2009. Section 5 discusses the empirical setting. Section 6 presents the results and section 7 concludes.

2. Literature review and hypotheses

The literature on the relationship between innovation activities and business cycle development is very comprehensive. In what follows we want to identify important firm-level and industry-level factors that explain pro-cyclical or anti-cyclical behaviour with respect to R&D investment.

2.1 Arguments and evidence in favour of pro-cyclical behaviour

While Schmookler (1966) emphasised demand-side factors as important driving factors for innovation activities, Schumpeter (1942) emphasised supply-side factors. Actually it appears that both components are important (see Arvanitis and Hollenstein 1994 for evidence for Switzerland). If we think in great technological inventions, like biotechnology, nanotechnology or important ICT (Information and Communication Technology) elements (for example, world wide web, personal computers), it is clearly that they caused a bunch of follow-on innovations that created promising markets. Following Schmookler (1966) such innovations are more likely if the economy is booming and they are less likely if demand is shrinking. In case innovation activities are predominantly financed by the cash-flow, innovation activities are likely to be pro-cyclical. In fact, Geroski and Glegg (1997)[1] found a positive relationship between demand and major innovations (or patents). Also Piva and Vivarelli (2007, 2009) found a significant demand-pull effect for innovations if companies are liquidity-constrained. For Switzerland especially the development of export markets (demand) show a positive relationship with innovation success of Swiss firms (see Woerter and Roper 2010). Geroski and Glegg (1997) found a less clear link between R&D investment and demand, since the fluctuations of R&D investments are limited by high adjustment costs.

[1] Geroski and Walters (1995) found that innovation activities are pro-cyclical. However, Collins and Yao (1998) showed that the Granger-causality test in Geroski and Walters (1995) shows some flaws. Collins and Yao (1998) used a VAR model and could not find any causality between innovation and business cycle based on the same data set as Geroski and Walters (1995).

R&D activities are not a product that can easily be traded. To some extent they are "sunk" investments and they can not be sold easily until they resulted in a product. It is also costly to stop a project and to pick it up at a later moment. Research knowledge has tacit components; it roots in the mind of single researchers. If they leave the firm, the knowledge is gone too. This may be especially true for firms with few specialized researchers. Hence, R&D expenditures are expected to fluctuate less with the business cycle compared to innovative products. Nevertheless, Guellec and Ioannidis (1999) based on industry level data as well as Rammer et al. (2004) based on firm-level data found a positive relationship between turnover (sales) and R&D expenditures. Also Mairesse et al. (1999) stated a positive relationship between market growth and R&D expenditures. This may be due to the cash-flow effect. Cash-flow plays an important role for R&D investments.

Arrow (1962) has already used R&D investments as an example for moral hazard, since the output of R&D activities can never be predicted from the input (see Arrow 1962, p. 172). Furthermore, there is greater information asymmetry between potential investors and researchers. It should be easier for researchers to assess the likelihood of technological success of R&D projects compared to investors, since the latter lack detailed information and experience with respect to the research processes. Therefore, it is difficult for investors to distinguish good from bad projects ('lemon problem'). In case the information asymmetry is too great, a market for R&D investments may disappear at all. Information asymmetry is expected to fluctuate with the business cycle (see Bernanke and Gertler 1989). The information asymmetry or principle-agent problem is mitigated if the net worth of the borrower increases, since financial distress causes higher agency costs. Since borrowers' net worth is pro-cyclical, there will be a decline in agency costs in booms and an increase in recessions. The pro-cyclicality of agency costs tends to make external R&D investments pro-cyclical as well.

These theoretical findings were confirmed by Aghion et al. (2008) for France. The authors argued that information asymmetries prevented French firms form increasing their investments in business downturn. Hall (1992) found a positive elasticity between R&D investments and cash-flow, controlling for a number of other factors, e.g. demand. Thus, Hall (1992) concludes that financial restraints rather than demand fluctuation prevent firms from R&D investments. Himmelberg and Petersen (1994) also found good reasons that cash-flow is important for R&D investments. They also stated that earlier studies did not find an effect of internal finance on R&D investments, since they predominantly looked at large firms. Large firms are less likely to be financially constrained compared to smaller firms. Himmelberg and Petersen (1994) looked at small high-tech firms. Since internal finance is likely to be pro-cyclical, R&D investments are likely to be pro-cyclical as well. Lerner (2010, p. 28/29) concludes from several studies that "Anglo-Saxon economies are more sensitive or show a greater responsiveness of R&D to cash-flow compared to continental Europe countries. This greater responsiveness of R&D may arise since they are financially constrained in a sense that they are viewing external financial resources as quite expensive (high expectations of rates of returns from investors). In Germany correlation between cash flow and R&D investments seems to be stronger for smaller firms compared to larger ones." Rammer et al. (2004) stated for Germany that SMEs are stronger effected by business cycle fluctuations compared to larger firms. However, the R&D expenditures of SMEs show a more moderate reaction upon turnover compared to large firms. Some rigidity on the R&D employment level may be responsible for this observed effect, since a further reduction of R&D activities - that are already on a low level - could mean to shut down R&D.

2.2 Arguments and evidence in favour of anti-cyclical behaviour

In a booming economy it is expected that costs for labour and other input factors for R&D activities are high and in recessions costs are clearly lower. Hence, opportunity costs are lower in recessions and firms would benefit if they could shift resources to R&D activities. If the economy improves and demand increases they could launch the new products and benefit from these investments. Aghion and Saint-Paul (1998) stated that R&D activities would be anti-cyclical if costs are pro-cyclical. Also Barlevy (2007) argued that based on opportunity costs rational firm behaviour would cause R&D to be anti-cyclical. Rafferty and Funk (2004) found that opportunity-cost effects are more likely for firms with large R&D budgets.

Rent displacement refers to the fear that introducing a new innovation will displace earnings from existing products. Since earnings of existing products are expected to be low in recessions, or even may dry up, resistance to introduce newer products or new versions of existing products may be lower (see Geroski and Glegg 1997). Thus, it should be easier to introduce innovations in recessions. This would run innovation activities anti-cyclical.

Firms are doing research in different technological fields. Some of them are fields with greater potential - so called high-technological opportunity fields - others show a lower potential - so called low-technological opportunity fields. Brouwer and Kleinknecht (1999) argued that innovators in high-opportunity fields have fewer problems with demand shocks or with financing R&D activities in recessions. They assume that this is related to market power, since they found little effects for firms that concentrate their R&D in certain technological fields (for example, information technology, new materials technology or biotechnology). However, technological opportunities are likely to be strongly related with R&D effort. Dugal and Morby (1995) found that firms with greater R&D investments are suffering less from sales declines during recessions. They found that more than 70% of firms that spent more than 5% of their sales in R&D experienced even a sales increase in recession. Tang (2002) investigated the country level and found that technical process reduces growth volatility. However there can be a "competitive effect", since Rammer et al. (2004) found for Germany that a change in world-wide research intensity of an industry has a negative effect on R&D expenditures of German firms in those technology fields. That means that R&D dynamic in

Germany took place in industries that are not characterized through a strong increase in international R&D.

2.3 The role of competition

Competition is a further important factor in order to explain pro- or anti-cyclicality of R&D investment. Starting with a Schumpeterian view (see Schumpeter 1942), concentrated markets with at least some passing monopoly power are more likely to have internal financial means to finance their R&D activities. But do they have incentives for R&D? Lacking competitive pressure large firms may tend to be overcautious and very bureaucratic and as a consequence they turn out to be less innovative. Especially in “bad” times they are likely to protect their markets rather than expand their markets through innovative products. This could be an argument that competition fosters innovative activities (see Geroski and Glegg 1997). However, firms in an atomistic type of competitive environment may not have access to sufficient financial means (internal and external) for permanent R&D activities. Thus, they may also refrain from innovation activities especially in recessions, when sales and cash-flow are likely to be low. This leads us to a view that neither monopoly nor atomistic competition is likely to be the most favourable competitive environment for innovation; an oligopolistic market with few R&D active firms seems to be most favourable. In a more stylized form we would see an “inverted U-shape” relationship between competition and innovation performance (see Aghion et al. 2005). These findings make it plausible that R&D expenditures in oligopolistic markets are likely to remain considerable even during recessions.

2.4 The role of labour costs

Factor costs are usually higher in an expanding economy and lower during recessions. Labour costs show some special characteristics. Firstly, labour supply is usually rather steadily. A lack of skilled people could seriously affect the R&D activities of firms. Since labour shortage and greater labour costs are more likely in a booming economy, it would be a rational firm behaviour to favour more R&D activities in recessions than in expansions. Actually we observe the opposite. Rammer et al. (2004) found that R&D personnel show a pro-cyclical development by trend. Greater demand and greater liquidity of firms in expansive economies may be the reason for this observation. However, R&D personnel fluctuate less than R&D expenditures across a cycle. This is due to the fact that firms cannot afford to loose skilled people and their specific (tacit) knowledge during a recession.

Since there is some rigidity in R&D labour fluctuations, it is unlikely that salaries would drop significantly during recessions. In contrast, sales are more volatile during a business cycle. Thus, R&D personnel – although more expensive in expansive economies – could be financed easier in good times than in recessions. This also contributes to the pro-cyclicality of R&D

employment. If labour supply is fluctuating (pro-cyclical) then Barlevy (2007) argued that R&D behaviour is pro-cyclical, too, although opportunity costs would push for anti-cyclical R&D activities.

2.5 Summing up: resulting hypotheses

In sum, we analyzed a number of factors that have a pro-cyclical or anti-cyclical effect on R&D investments or innovative behaviour. While demand factors and cash-flow clearly work for a pro-cyclical effect of innovation behaviour, opportunity costs, rent displacement are clearly anti-cyclical. Great technological opportunities and more "oligopolistic" type of competition increase the R&D intensity of firms and they also make R&D expenditures less exposed to fluctuating sales. Labour supply can show pro-cyclical as well as anti-cyclical effects, depending on the employment and salary flexibility of firms. If flexibility is low and sales fluctuate strongly with the business cycles then R&D employment is likely to be pro-cyclical. Whether R&D investments or innovations are pro-cyclical or anti-cyclical depends on the just mentioned factors. Since restraints in financial means are expected to be stronger than the "opportunity effect" (see Rafferty and Funk 2008), one could expect some tendency for pro-cyclical fluctuation. However, at the end what holds is an empirical question. Based on available data and the literature we test empirically the following hypotheses:

a) Controlling for the past demand development we would assume that firms with anti-cyclical R&D investment (sales share of R&D investments) would not lack internal financial resources for financing innovation projects. Moreover, a good past demand development increases the financial opportunities of firms and hence, enables firms to invest anti-cyclically in R&D in the future.

b) Larger firms are more likely to finance R&D internally and they should be less dependent on short-term market fluctuations. Hence, they are likely to exploit opportunity costs and invest anti-cyclically in R&D.

c) External R&D cooperation increases the flexibility of R&D activities of a firm. Hence, it is expected that such firms are more likely to make use of opportunity costs. They are more likely to invest anti-cyclically in R&D.

d) It is expected that firms with larger sales share of R&D investments would suffer less from sales declines during recessions than firms with small R&D budgets. Hence, such firms are likely to invest anti-cyclically in order to make use of opportunity costs.

e) Firms with intensive price competition in their main markets are likely to have difficulties to finance their R&D, since their price-cost margins are expected to be low. In business good times they are expected to have less problems to finance R&D. Hence, their investment behaviour is expected to be pro-cyclical.

f) High average personnel costs point at well-educated and experienced staff that is not easily substituted, if once they are dismissed. Hence, firms have the tendency to keep their "expensive" high-qualified R&D employees. Clearly, such personnel could be financed easier in good times than in recessions. This would point at the pro-cyclicality of R&D investments. Hence firms with great average personnel costs are likely to invest pro-cyclically.

3. Data

We used two sources of data for this investigation. First, we employed data at industry level on the cyclical movement of business activity in the period 1999-2009 in Swiss manufacturing. These data are stemming from the monthly Swiss Business Survey (see http://www.kof.ethz.ch/surveys/bts/ind/pdf/fb_imt_de.pdf) and were first aggregated to 3-digit industry level (30 industries) and then transformed to annual data (average of monthly data). We constructed a composite indicator of business activity based on the following three single indicators of business activity: 'incoming orders', 'production' and 'order backlog' (see Table 3).

Second, we used firm-level data of three waves (2002, 2005, 2008) of the Swiss Innovation Survey (see http://www.kof.ethz.ch/surveys/structural/panel/pdf/fb_inno_2008_de.pdf). The survey yields information on the R&D expenditures, the firm size, the employees' education level, the competition conditions (intensity of price and non-price competition), and external R&D activities such as R&D cooperation with different business partners and institutions and/or contract (external) R&D. Pooling data from two different sources and building differences of R&D expenditures and indicators for cyclical movement between two points of time led finally to a sample of 980 available observations of firms with R&D activities. The basic descriptive statistics as well as the correlation matrix of the variables used in the econometric part are found in the Appendix in the Table A.1 and A.2 respectively.

4. R&D and business cycle development in Swiss manufacturing 1999-2009: The main facts

The three business indicators (incoming orders, order backlog, and production) as well as the composite indicator for economic activity in the Swiss manufacturing sector in the period 1999-2009 show a strong cyclical pattern with two peaks in 2000 and 2007 respectively and two troughs in 2002 and 2009 respectively (Figure 1). Almost all of the 30 3-digit industries considered in this study show a similar cyclical pattern. There are some exceptions (e.g., pharmaceutical industry), but they are too few to affect the overall picture.

Table 1 shows the shares of firms that behave differently with respect to R&D investment when the overall business conditions change (see Table 3 for the definition of pro-cyclical, anti-cyclical and non-systematic behaviour). About 42% of all firms with R&D activities behave pro-cyclically, only 17% behave anti-cyclically and the rest (about 40%) shows no systematic behaviour with respect to cyclicality. Pro-cyclically reacting firms show an asymmetric behaviour. 83% of them react only to *positive* changes of the overall business conditions, 17% only to *negative* changes of the overall economic activity. Economically relevant is the fact that there is considerable behaviour variety in our sample that allows testing alternative hypotheses.

Table 2 shows the distribution of the various behaviour categories by industry. In every industry we found more pro-cyclical behaving than anti-cyclical behaving firms. But there are four industries, in which the group of firms with "non-systematic" behaviour is the largest one: wood processing, printing, metal working and other manufacturing, all four of them rather low-tech industries with a low R&D intensity. In two more industries are the groups of firms with "non-systematic" behaviour" and pro-cyclical behaviour about of the same magnitude: food and glass, stone, clay, also industries with a low R&D intensity. Finally, machinery and electronics/instruments, two of the most innovative industries in Switzerland, show relatively high shares of firms with that react pro-cyclically only to negative changes of economic conditions.

5. Empirical setting

5.1 Dependent variables

We classified firms as to their R&D behaviour when the level of business activity changes cyclically. We distinguished three basic behaviour categories: non-systematic, pro-cyclical and anti-cyclical behaviour. The group of pro-cyclically behaving firms was further broken down in two sub-categories of *asymmetric* pro-cyclical behaviour: firms reacting pro-cyclically only when the economic situation (according to the business activity indicator; see Table 3) is improving (pro-cyclical positive) and firms reacting pro-cyclically only when the economic situation is deteriorating (pro-cyclical negative). Each firm in the sample was placed in one of these categories. The exact definition is found in Table 3. Based on this classification we constructed two multinomial variables that served as dependent variables of the empirical model: a first one that distinguishes three basics behaviour categories (non-systematic, pro-cyclical and anti-cyclical) and a second one that takes additionally into consideration a refinement of pro-cyclical behaviour (asymmetric *positive* and asymmetric *negative* pro-cyclical behaviour).

5.2 Independent variables

We regressed the two multinomial variables against a vector of independent variables that allow testing the hypotheses (a) to (f) in section 2 (see Table 3). The variable D measures past demand development; a positive sign of this variable in then estimates for anti-cyclically behaving firms is a hint that demand development might increase the financial opportunities of firms and hence enable them to invest anti-cyclically (*hypothesis a*). Additional evidence on this issue would yield a negative relationship of the variable FIN showing that lack of own financial resources can be a considerable hindrance of anti-cyclical investment in R&D. Moreover, we expect larger firms (variable FSIZE) to be able to finance R&D internally at a larger extent as smaller firms, with the consequence that they can better utilize opportunity costs and invest anti-cyclically in R&D (*hypothesis b*). Further, we expect anti-cyclically investing firms to use more external (innovation-relevant) knowledge (*hypothesis c*) and invest more in R&D as pro-cyclically behaving firms (*hypothesis d*). Thus, for pro-cyclically behaving firms a positive sign of the variable EXT (or alternatively of any of the variables UNIV, VERT, GROUP or COMP referring to different types of R&D cooperation partners) and a positive sign of the R&D/S variable respectively is to be interpreted as evidence supporting hypothesis (c) and hypothesis (d) respectively.

Firms with high labour costs per employee are likely to invest pro-cyclically. Thus we expect a positive sig of the variable LLCOST_L in the estimates for pro-cyclically behaving firms (*hypothesis e*). Firms operating under conditions of high price pressure are likely to behave pro-cyclically with respect to R&D intensity (*hypothesis f*). Thus a positive sign of the variable IPC in the estimates for pro-cyclically behaving firms can be interpreted as evidence in favour of hypothesis (f). We also include in our model a further competition variable referring to the non-price dimensions of competition (variable INPC), for which we expect the opposite sign as for price competition. We also include in our model controls for the high-tech sector and the year, in which the survey has taken place.

In sum we estimate the following functional forms:

$$DEP_{it} = \beta_0 + \beta_1 R\&D/S_{it-1} + \beta_2 D_{it-1} + \beta_3 FIN_{it-1} + \beta_4 LLCOST\_L_{it-1} + \beta_5 SHORT\_RD_{it-1} + \beta_6 EXT\_NET_{it-1} + \beta_7 IPC_{it-1} + \beta_8 INPC_{it-1} + \beta_9 FSIZE_{it-1} + \beta_{10} HIGHTECH_i + \beta_{11} TDUM\_05_i + e_i \quad (1)$$

$$DEP_{it} = \beta_0 + \beta_1 R\&D/S_{it-1} + \beta_2 D_{it-1} + \beta_3 FIN_{it-1} + \beta_4 LLCOST\_L_{it-1} + \beta_5 SHORT\_RD_{it-1} + \beta_6 UNIV_{it-1} + \beta_8 VERT_{it-1} + \beta_9 GROUP_{it-1} + \beta_{10} COMP_{it-1} + \beta_{11} IPC_{it-1} + \beta_{12} INPC_{it-1} + \beta_{13} FSIZE_{it-1} + \beta_{14} HIGHTECH_i + \beta_{15} TDUM\_05_i + e_i \quad (2)$$

$$DEP_{it} = \varepsilon(0,1,2)$$

or

$$DEP_{it} = \varepsilon(0,1,2a,2b)$$

DEP is the multinomial dependent variable (exclusive categories) that predetermines also the econometric method to be used. We applied a multinomial probit estimator ('mprobit' procedure in STATA), at which the independent variables are lagged one period. Hence, we are estimating the relationship between firm characteristics in the past and the DEP in the coming period (how R&D intensity response to business cycle fluctuation). This setting prevents that our estimations are driven by endogeneity of R&D/S. Furthermore, following Greene (2003, p. 727) the IIA (independence of irrelevant alternatives) rule does not apply in this case.

6. Results

6.1. Some Descriptive Results

Table 4 shows how the most important innovation-relevant characteristics used in this study are distributed among the three main categories of cyclical behaviour and the two sub-groups of pro-cyclically behaving firms. Both price and non-price pressure is felt primarily by firms behaving non-systematically and those with negative-pro-cyclical behaviour. The latter fact is in accordance with theoretical expectation. External contacts for knowledge acquisition are more frequent for positive-pro-cyclically behaving firms than for anti-cyclically operating firms (i.e. contrary to theoretical expectation); but they are more frequent for anti-cyclically behaving firms than those operating negative-anti-cyclically (i.e. in accordance to theoretical expectations). Thus, there is much behaviour heterogeneity that has to be taken into account in the empirical analysis. A similar pattern as for the overall variable “external contacts” is found also for the single cooperation partners (universities, suppliers/clients, competitors, firms of the same group).

6.2. Econometric Results

The results in Table 5 (columns 2 and 4) show that pro-cyclically behaving firms are more likely to pay higher wages (LCOST_L) and operate in markets with a high price pressure (IPC) than anti-cyclically behaving firms (reference group). Thus, the hypotheses (e) and (f) seem to be backed by the estimates. No differences between pro-cyclical and anti-cyclical behaviour could be found with respect to non-price competition (INPC).

Further, we see that the likelihood of pro-cyclical behaviour is related to lower R&D intensity (R&D/S) and significantly weaker relationship to demand development (D) than it is the case for anti-cyclically behaving firms. Looking at these results from the point of view of anti-cyclical behaviour, it appears that the hypotheses (a) and (d) respectively are confirmed. No difference as to lack of internal financial resources (FIN) was found between pro-cyclical and anti-cyclically behaving firms. The lack of internal finance resources appears to be a problem rather for non-systematic than for anti-cyclical behaviour. Hypothesis (d) receives only partly additional support by the results for the variable FIN. The variable SHORT_RD did not show any effect in all estimates in Table 5 and Table 6.

We do not find any difference between anti-cyclical and pro-cyclical behaviour with respect to firm size (FSIZE). Larger firms do not seem to be stronger inclined to anti-cyclical behaviour than smaller ones, as it is postulated in hypothesis (b). However, this hypothesis receives some support when anti-cyclical behaviour is compared with non-systematic behaviour (column 1): the likelihood of behaving non-systematically is negatively correlated with firm size or the other way around the likelihood of anti-cyclical behaviour is positively correlated with firm size.

According to hypothesis (c) it is expected that the acquisition of external knowledge (EXT_NET) is a characteristic for anti-cyclical investment behaviour of firms. This is the case only when anti-cyclical behaviour is compared with non-systematic behaviour but not when compared with anti-cyclical behaviour. Hence, hypothesis (c) is only partly confirmed. There is some rather weak evidence that pro-cyclical and no-systematic behaviour is related to the use of university knowledge (columns 3 and 4 in Table 5), which is contrary to hypothesis (c). The more refined results in Table 6, column 6 show that the university knowledge effect holds primarily for the positive-pro-cyclically behaving firms (see below). The negative effect of EXT_NET is traced back to the use of knowledge from firms of the same firm group or firm conglomerate (GROUP).

Finally, firms in the high-tech sector of the manufacturing sector (HIGHTECH) are more likely to be found among anti-cyclically behaving firms than among non-systematically behaving firms, but no difference with respect to the affiliation to the high-tech sector was found between anti-cyclically and pro-cyclically behaving firms. The likelihood of behaving pro-cyclically has been significantly higher in the period beginning with 2005 than in the earlier period beginning with 2002, when compared with anti-cyclical behaviour.

Some additional insights are gained when pro-cyclical behaviour is broken down to positive-pro-cyclical behaviour for firms reacting pro-cyclically only when the economic situation is improving (boom) and negative-pro-cyclical behaviour for firms reacting pro-cyclically only when the economic situation is deteriorating (trough). The results in Table 6 show that the effects of demand development and R&D intensity are found for both sub-categories of pro-cyclical behaviour. Thus, the hypotheses (a) and (d) are holding on a wide basis. The effect of high labour costs per employee (LLCOST_L) comes primarily from firms with a negative-pro-cyclical behaviour, the price competition effect (IPC) is traced back primarily to the positive-pro-cyclical behaving firms. Hence, these results lead to a (data-driven) refinement of the hypotheses (e) and (f), each of them holding for a specific sub-group of pro-cyclically behaving firms.

The more detailed results for various R&D cooperation partners in Table 6 (columns 5 and 6) show – as already mentioned above – a positive university knowledge effect for positive-pro-cyclically behaving firms as compared to anti-cyclically behaving firms that is contrary to theoretical expectations. Thus, the flexibility effect of R&D cooperation as postulated in hypothesis (c) does not hold for the cooperation with universities. A further result is the negative effect of horizontal R&D cooperation, which is in accordance with theoretical expectations but did not show with the overall variable for external knowledge EXT_NET (see table 5, column 3).

7. Conclusions

New elements of our analysis are: (a) the identification in our data of three main types of R&D investment behaviour, namely anti-cyclical, pro-cyclical and non-systematic with respect to the fluctuation of overall economic activity as measured by a standard composite indicator of the business conditions at industry level and (b) the investigation of a series of hypotheses as to innovation-relevant firm characteristics that underline the three different behaviour categories.

About 42% of all firms with R&D activities behave pro-cyclically, only 17% behave anti-cyclically and the rest (about 40%) shows no systematic behaviour with respect to cyclicality. Economically relevant is the fact that there is considerable behaviour variety in our sample that allows testing alternative hypotheses.

To this end, we analyzed a number of factors that have a pro-cyclical or anti-cyclical effect on R&D investments or innovative behaviour. In sum, we found that firms can benefit from low opportunity costs through anti-cyclical R&D investments if: (1) they are confronted with stronger demand effects (compared with anti-cyclical behaviour; hypothesis a); (2) they have a relatively large sales share of R&D expenditures (hypothesis d); (3) they use have external R&D relationships (only compared with non-systematic behaviour, thus only partial confirmation of hypothesis c); (4) they have rather low average labour costs (compared with pro-cyclical behaviour; hypothesis f); (5) they are not exposed to intensive price competition (for example, because they operate in international market niches; hypothesis e), (6) they are relatively large (hypothesis b); and (7) they belong to high-tech industries. An additional characteristic of anti-cyclical behaving firms is that compared with pro-cyclical firms, particularly positive-pro-cyclically operating firms, they are less frequently cooperating with universities.

From a policy point of view the results indicate that innovation policy can contribute to mitigate the cyclical fluctuation of R&D investments through considering the just mentioned factors in their promotion activities. This would not only help firms make use of lower opportunity costs at recessions, it would also contribute to dampen the overall business fluctuation.

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Tables

Figure 1: Business indicators 1999-2009

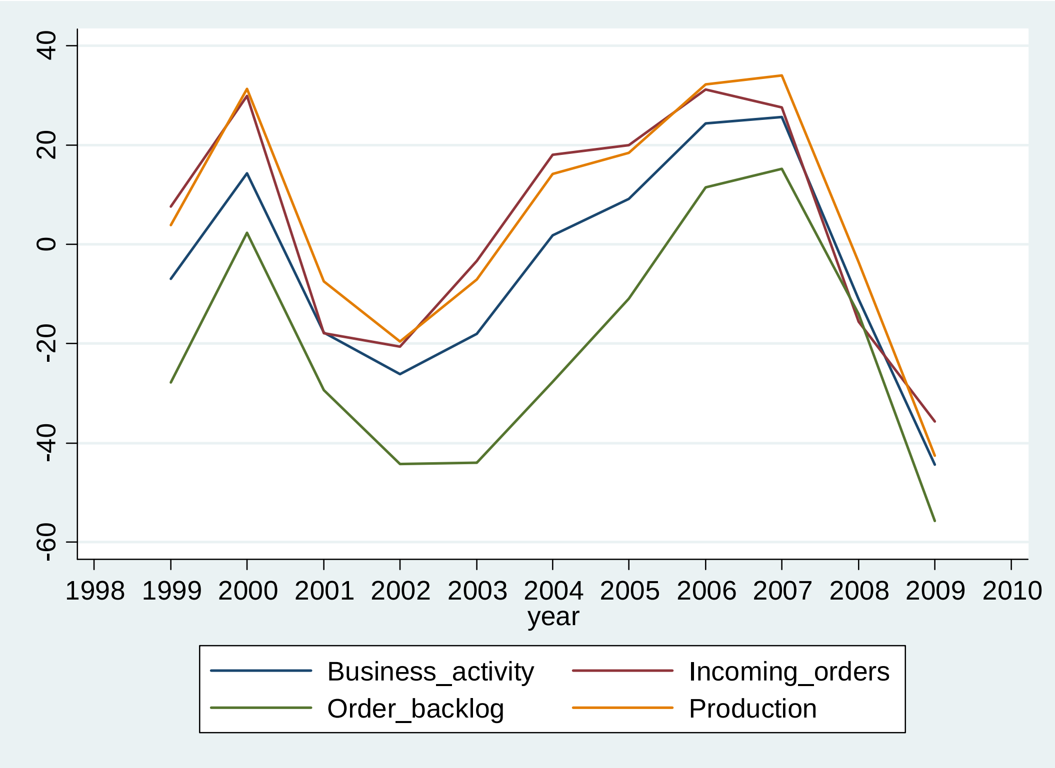

Table 1: Business cycle and firm behaviour with respect to R&D intensity

		N	Percentage share
Non-systematic		396	40.41
Anti-cyclical		171	17.45
Pro-cyclical	Pro-cyclical / negative	72	7.35
	Pro-cyclical / positive	341	34.80
Total		980	100

Number of observations 2002, 2005. See Table 4 for the definition of the variables.

Table 2: Firms with pro-cyclical, anti-cyclical or non-systematic behaviour as to R&D intensity by industry (number of observations 2002, 2005)

	Non-systematic	Anti-cyclical	Pro-cyclical		Total
			Pro-cyclical negative	Pro-cyclical positive	
Food, beverage, tobacco	36	6	10	28	80
Textiles	7	9	0	16	32
Clothing	2	2	0	2	6
Wood processing	19	5	0	14	38
Paper	8	3	0	11	22
Printing	37	5	7	20	69
Chemicals	7	19	0	36	62
Plastics, rubber	38	4	0	10	52
Glass, stone, clay	22	7	0	15	44
Metal	7	4	0	6	17
Metal working	93	7	2	45	147
Machinery	54	37	34	60	185
Electrical machinery	11	15	0	18	44
Electronics, instruments	65	52	34	78	229
Transportation vehicles	6	3	1	3	13
Other manufacturing	19	3	0	8	30
Total	396	171	72	341	980

See Table 4 for the definition of the variables.

Table 3: Definition of variables

Variables	Definition
Dependent variables (DEP) The classification of the firms (non-systematic, anti-cyclical, pro-cyclical) was based on the *signs* of the *change* of the composite indicator of business activity and the *change* of R&D intensity between the periods 2000-2003 und 2003-2005 as well as 2003-2005 and 2006-2008. Concretely, we calculated the average values of the composite indicator of business activity over the three 3-year periods 2000-2002, 2003-2005 and 2006-2008). The *change* of the level of business activity at 3-digit industry level was measured by the difference of the average values of the periods 2000-2002 and 2003-2005 as well as 2003-2005 and 2006-2008. The R&D intensity was recorded in the survey as the average value of the three 3-year periods 2000-2002, 2003-2005 and 2006-2008). The *change* of the R&D intensity was then measured by the difference of the average values of the periods 2000-2002 and 2003-2005 as well as 2003-2005 and 2006-2008. The firms are broken down to groups as follows: (a) in the three groups 0, 1 und 2 (see below) and (b) in the four groups 0, 1, 2a und 2b (where the latter two are sub-groups of group 2; see below). The multinomial variable DEP (0, 1, 2) served as dependent variable for the estimates in Table 5, die multinomial variable DEP (0, 1, 2a, 2b) for the estimates in Table 6.	
0: non-systematic behaviour (as to R&D intensity)	This group contains firms the R&D intensity of which does not show a systematic (monotonously positive or negative) relationship to the cyclical indicator of business activity. This means that either the R&D intensity increases or decreases during a certain period, while the business activity indicator remains (almost) constant, or the R&D intensity remains (almost) constant, while the overall business situation improves or deteriorates.
2: pro-cyclical behaviour (as to R&D intensity)	This group contains firms for which the business activity indicator of the respective 3-digit industry and the R&D intensity change during a certain period in the *same* direction (both variables either increase or decrease)
2a: pro-cyclical behaviour / negative	This sub-group of contains firms that behave pro-cyclical only for *negative* changes. This means that the R&D intensity decreases when the business activity indicator falls, but the R&D intensity does not increase when the business activity indicator rises.
2b: pro-cyclical behaviour / positive	This sub-group contains firms that behave pro-cyclical only for *positive* changes. This means that the R&D intensity increases when the business activity indicator rises, but the R&D intensity does not decrease when the business activity indicator falls.
1: anti-cyclical behaviour	This group contains firms for which the business activity indicator of the respective 3-digit industry and the R&D intensity change during a certain period in the *opposite* direction (R&D intensity increases when the business activity indicator falls and the other way around).
Independent variables	
Business activity indicator	Composite indicator of business activity based on the following three single indicators of business activity: 'incoming orders', 'production' and 'order backlog'. Monthly data of the three single indicators at firm level were used to calculate the composite indicator at a monthly basis. These monthly data were first aggregated to 3-digit industry level (30 industries) and then transformed to annual data using the average of the monthly data.
Innovation-relevant characteristics	

R&D/S	R&D intensity: R&D expenditures divided by sales
D	Assessment of the demand development in the last three years; five-level ordinal variable (1: “very weak”; 5: (very strong”)
FIN	Shortage of own funds; five-level ordinal variable (1: „not important”; 5: „very important“)
SHORT_RD	Shortage of R&D personnel; five-level ordinal variable (1: „not important”; 5: „very important“)
LLCOST_L	Natural logarithm of labour costs per employee
EXT_NET	R&D cooperation and/or contract (external) R&D (dummy variable)
UNIV	R&D cooperation with universities (dummy variable)
VERT	R&D cooperation with suppliers and/or clients (dummy variable)
GROUP	R&D cooperation with firms of the same group (dummy variable)
COMP	R&D cooperation with competitors (dummy variable)
IPC	Intensity of price competition; five-level ordinal variable (1: „very weak“; 5: „very strong“)
INPC	Intensity of non-price competition; five-level ordinal variable (1: „very weak“; 5: „very strong“). Non-price competition includes product differentiation, frequent introduction of new products, technical advance, high awareness of client needs, additional supply of services
FSIZE	Number of employees (in full-time equivalents)
HIGHTECH	Dummy variable for high-tech manufacturing: chemicals (NACE classification: 24), plastics (25), machinery (29), transportation vehicles (34, 35), electrical machinery (31), electronics/instruments (30, 32, 331-334)
TDUM_05	Dummy variable for the year 2005

Table 4: Firm characteristics that are relevant for innovation and anti-cyclical, pro-cyclical or non-systematic behaviour as to the R&D intensity

	All firms		Non-system.	Anti-cyclical.	Pro-cyclical	
					Pro-cyclical negative	Pro-cyclical positive
(High) Intensity of non-price competition	37.7	of which	34.7	21.1	9.8	34.4
(High) Intensity of price competition	76.3	of which	40.0	16.2	7.1	36.8
External contacts (R&D cooperation and/or contract (external) R&D	39.3	of which	18.4	28.3	13.0	40.3
R&D cooperation with universities	12.3	of which	15.8	28.3	10.8	45.0
R&D cooperation with suppliers and/or clients	16.5	of which	17.4	29.8	10.6	42.2
R&D cooperation with firms of the same group	12.0	of which	15.4	33.3	11.1	40.2
R&D cooperation with competitors	6.0	of which	20.3	27.1	5.1	47.5

See Table 4 for the definition of the variables.

Table 5: Innovation-relevant characteristics of firms with pro-cyclical, anti-cyclical or non-systematic behaviour with respect to R&D intensity; manufacturing; 2000-2008

	0: non-systematic	2: pro-cyclical	0: non-systematic	2: pro-cyclical
R&D/S	-22.347***	-6.013***	-27.000***	-6.543***
	(3.109)	(1.823)	(3.166)	(1.812)
D	-0.093	-0.174***	-0.120*	-0.189***
	(0.071)	(0.068)	(0.071)	(0.069)
FIN	0.103*	0.016	0.123**	0.025
	(0.062)	(0.059)	(0.062)	(0.059)
LLCOST_L	0.208	0.428*	0.044	0.413*
	(0.258)	(0.244)	(0.257)	(0.245)
SHORT_RD	-0.041	0.042	-0.062	0.045
	(0.066)	(0.062)	(0.065)	(0.062)
EXT_NET	-1.015***	-0.102		
	(0.174)	(0.160)		
UNIV			0.574*	0.538*
			(0.345)	(0.292)
VERT			-0.215	-0.165
			(0.318)	(0.270)
GROUP			-0.906***	-0.349
			(0.322)	(0.266)
COMP			-0.278	-0.144
			(0.364)	(0.302)
IPC	0.159**	0.154**	0.147*	0.145**
	(0.079)	(0.075)	(0.079)	(0.075)
INPC	-0.094	0.026	-0.137	0.028
	(0.094)	(0.089)	(0.093)	(0.088)
FSIZE	-0.115**	-0.066	-0.170***	-0.065
	(0.062)	(0.058)	(0.062)	(0.058)
HIGHTECH	-0.428***	-0.131	-0.431***	-0.132
	(0.161)	(0.154)	(0.161)	(0.155)
TDUM_05	-0.713***	0.712***	-0.693***	0.727***
	(0.156)	(0.147)	(0.155)	(0.148)
Const.	-0.130	-4.272	1.991***	-4.104
	(2.889)	(2.735)	(2.867)	(2.743)
N	980		977	
Wald chi2	281.6***		260.2***	
Log L	-830.6		-841.8	

Multinomial probit estimates; reference group: 1: anti-cyclical; ***. ** and 3 resp. denote statistical significance at the 1%, 5% or 10% test level resp.

Table 6: Additional refinements: innovation-relevant characteristics of firms with Pro-cyclical, anti-cyclical or non-systematic behaviour with respect to R&D intensity; manufacturing; 2000-2008

	0: non-systematic	2a: pro-cyclical-negative	2b: pro-cyclical-positive	0: non-systematic	2a: pro-cyclical-negative	2b: pro-cyclical-positive
R&D/S	-21.618***	6.379**	-13.378***	-26.000***	8.434**	-14.159***
	(3.118)	(2.873)	(2.457)	(3.152)	(3.124)	(2.371)
D	-0.087	-0.174*	-0.162**	-0.112	-0.181*	-0.178**
	(0.071)	(0.097)	(0.072)	(0.071)	(0.099)	(0.073)
FIN	0.095	0.058	-0.003	0.113*	0.063	0.004
	(0.062)	(0.091)	(0.063)	(0.062)	(0.092)	(0.063)
LLCOST_L	0.175	1.135***	0.309	0.008	1.140***	0.272
	(0.258)	(0.430)	(0.255)	(0.257)	(0.439)	(0.257)
SHORT_RD	-0.036	-0.078	0.065	-0.056	-0.104	0.075
	(0.066)	(0.098)	(0.065)	(0.062)	(0.101)	(0.066)
EXT_NET	-0.995***	0.019	-0.093			
	(0.173)	(0.245)	(0.172)			
UNIV				0.588*	-0.242	0.695**
				(0.345)	(0.467)	(0.316)
VERT				-0.275	0.088	-0.291
				(0.317)	(0.426)	(0.295)
GROUP				-0.866***	-0.284	-0.298
				(0.322)	(0.418)	(0.290)
COMP				-0.210	-1.245***	0.174
				(0.364)	(0.566)	(0.318)
IPC	0.154**	-0.144	0.211***	0.146*	0.240	0.210***
	(0.079)	(0.121)	(0.079)	(0.078)	(0.178)	(0.079)
INPC	-0.109	0.209	-0.025	-0.149	-0.155	-0.023
	(0.095)	(0.178)	(0.092)	(0.094)	(0.122)	(0.092)
FSIZE	-0.107*	-0.005	-0.060	-0.163***	0.038	-0.067
	(0.062)	(0.090)	(0.062)	(0.062)	(0.093)	(0.062)
HIGHTECH	-0.434***	-0.076	-0.128	-0.440***	0.024	-0.149
	(0.161)	(0.241)	(0.161)	(0.160)	(0.246)	(0.163)
TDUM_05	-0.534***	-14.020	1.393***	-0.519***	-15.896	1.423***
	(0.157)	(3.9E+06)	(0.162)	(0.156)	(2.9E+07)	(0.163)
Const.	-0.187	-12.683***	-3.587	2.313	-12.884***	-3.184
	(2.888)	(4.805)	(2.863)	(2.871)	(4.899)	(2.884)
N	980			977		
Wald chi2	382.8***			382.8***		
Log L	-888.7			-888.7		

Multinomial probit estimates; reference group: 1: anti-cyclical; ***. ** and * resp. denote statistical significance at the 1%, 5% or 10% test level resp.

Appendix:

Table A.1: Descriptive statistics

Variable	N	Mean	Std. Dev.	Min	Max
D	980	2.993	0.909	1	5
FIN	980	2.389	1.093	1	5
SHORT_D	980	2.240	1.320	1	5
LLCOST_L	980	11.270	1.198	8.517	12.432
INPC	980	3.169	0.313	1	5
IPC	980	4.049	0.855	1	5
EXT	980	0.393	0.963	0	1
R&D/S	980	1.017	0.487	0	1
UNIV	977	0.123	0.328	0	1
VERT	977	0.165	0.371	0	1
GROUP	977	0.120	0.325	0	1
COMP	977	0.060	0.238	0	1

Table A.2: Correlation matrix

	D	FIN	SHORT _D	LLCOST _L	INPC	IPC	EXT	R&D/S	UNIV	VERT	GROUP	COMP
D	1.000											
FIN	-0.114	1.000										
SHORT_D	0.034	0.168	1.000									
LLCOST_L	0.059	-0.138	0.010	1.000								
INPC	0.148	0.009	0.002	0.010	1.000							
IPC	-0.041	0.035	0.045	0.076	0.004	1.000						
EXT	0.155	-0.114	0.127	0.190	0.165	0.022	1.000					
R&D/S	0.088	0.020	0.084	0.015	0.024	-0.048	0.346	1.000				
UNIV	0.118	-0.063	0.047	0.118	0.070	0.042	0.466	0.257	1.000			
VERT	0.101	0.052	0.104	0.132	0.092	0.011	0.553	0.252	0.691	1.000		
GROUP	0.091	-0.073	0.062	0.103	0.067	0.017	0.459	0.176	0.611	0.635	1.000	
COMP	0.018	-0.042	0.021	0.075	0.060	0.005	0.315	0.109	0.345	0.449	0.281	1.000