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Empirical evidence for Denmark

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Market structure, publicly and privately financed R&D spending. Empirical evidence for Denmark.

by

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Abstract

In this paper we analyse the determinants of R&D spending in Danish firms and industries in the nineties. We also examine the complementarity and substitution between publicly and company financed R&D spending taking into account the influence from market structure, barriers of entry, demand conditions and other economic factors of the market and the firm. The empirical models of R&D spending are estimated both on industry and on firm level data. This allows us to examine how the investment R&D-activities differ according to differences in the organisation of the firm, firm size and the debt burden of the firms.

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1. Introduction

The development of new products and cost-saving technologies has been an important aspect of economic growth. The innovations may be even more important for the rise in economic prosperity in the future as the effects from accumulation of more capital and other factors of production per capita diminish due to the law of decreasing returns. Already today the rise in total factor productivity is the most important factor behind economic growth in the developed countries.

It is therefore important to understand how the aggregate level of innovative activities is determined. Measuring the innovation activity on the input side as the total amount spent on research and development is therefore important in determining the factors affecting the amount of R&D in the different industries or in the economy as a whole. Is the amount spent on R&D too high or too low in the industries? The answers to these questions also have important implications for publicly financed research and policy questions concerning the design and subsidisation of research programs in the private sector.

The share of GDP spent on R&D differs considerably between the OECD countries. Denmark is among the countries spending least on R&D. This also holds for individual industries, but the reason for this has not been examined in any depth. In this paper we examine the variation in the R&D intensity across 284 Danish industries and we study how this variation can be explained by differences in the market structure across the industries. There is, however, also considerable variation in research intensity among firms within the same industry. This variation which is the subject of the second part of our empirical analysis could be due to differences in firm characteristics such as firm size, market share, organisation of the firm etc. We make use of a Danish survey of 2000 firms with detailed information on R&D expenditure.

In the next section the key theoretical arguments behind the conventional empirical models of the R&D intensity differentials are discussed. The discussion leads to the specification of empirical models both at the industry level and firm level in section 3. Section 4 describes the data set to be used in the analysis. The results of our empirical analysis are set out in section 5. Section 6 concludes.

The results imply that the financial position of the firm, profitability, market structure, demand conditions and the source of financing affects the probability and intensity of R&D investments.

2. Determinants of R&D - key theoretical arguments

In this section we discuss different theoretical arguments which have focused on the innovation activity of the firm. Some of the empirical studies in this field are briefly discussed as well.

2.1. Market structure and R&D intensity

Schumpeter's (1942) well-known hypothesis is that there will be less innovation in competitive industries. However, this rejection of perfect competition does not necessarily imply that monopoly is the best market structure for promoting innovation activities as his hypothesis often has been interpreted. On the other hand, Schumpeter emphasised the idea that large-scale firms were the ideal vehicles for generating technical advances as they can benefit from the scale economies in production, marketing, financing and R&D. Of course, large firms are often synonymous with monopolised industries. However they can also be found in more competitive industries. For a survey of the earlier empirical studies of the relationship between market structure and research and development intensity, see Kamien and Schwartz (1975).

As firm size is not equally distributed within an industry, an important aspect of market structure is the market share of the firm. As with the market concentration the research intensity can be expected to increase with market share but level off and may fall when a company captures the whole market.

Challenging the Schumpeterian hypothesis, Arrow (1962) shows that the competitive firms have a strong incentive to invest in cost reducing innovations compared to monopolistic firms. The reason for this is that the return from successful innovation will include a monopoly rent, which the monopolistic firm already has. Another theoretical argument against the Schumpeterian hypothesis is the general notion of slack or X-inefficiency under monopolistic conditions, see Leibenstein (1966). Firms in monopolistic market positions may enjoy higher profits and, therefore, be lax and inefficient and fail to pursue the innovation opportunities in their markets.

In fact, in oligopolistic industries the relationship between market concentration, the market share of the firm and R&D intensity becomes much more blurred. One reason for the complexity is that the R&D intensity not only depends on the firm's demand and costs, but also on the interaction with its competitors concerning their level of R&D activities. Moreover, this strategic decision concerning their spending on R&D involves returns from new products in markets that do not yet exist. There are several different theoretical models focusing on different aspects of this strategic competition and they come up with different conclusions. We will focus on two directions in this theoretical development.

In the first type of models, innovation is considered as a continuous activity improving the firms' products and their demand in the same way as advertising. Needham (1975) modelled R&D in this product innovation context and showed that the conditions for optimality of the R&D intensity are analogous to the well-known Dorfman-Steiner condition for advertising. This implies that there will be a higher research intensity in less competitive and more profitable industries. The reason is straightforward: without a positive price-cost margin it does not pay for the firm to invest in R&D or advertising to promote the demand for its product. The condition also implies that the intensity will be higher in more concentrated industries where firms can internalise the benefits of their research through patent or product differentiation. This may be more difficult to achieve in industries with a large number of competing firms.

Taking account of rivalry between the firms where the demand for a firm's product also depends on the research intensity in other firms suggests a lower R&D intensity in highly concentrated industries. The reason for this is that if competitors match other firms spending on R&D, there will be a general improvement in product quality. The firm's market share will therefore be unaffected and as a result the firm will have a lower return on its R&D activities. Firms in highly concentrated industries might therefore collude and lower the amount spent on R&D in order to avoid this offsetting investment in product innovations. As a consequence there will be an inverted U-relation between R&D intensity and market concentration with a low level of research in highly competitive and in very concentrated industries. Lunn and Martin (1986) have extended the model to include process innovation and showed that the R&D intensity also depends on the share of production costs and the sensitivity of cost reduction to R&D investment.

The second type of models focuses on the right timing of the innovations. For an early contribution, see Scherer (1967). The key idea in these models is that the return to innovations is higher, the more quickly new products can be introduced to the market, either by taking a patent or as a reward to the first mover. Speeding up the research and development process also raises the costs, and the optimal time path thus involves a trade-off between these costs and the first mover benefits. The patent race model points to more rapid innovation in markets where the numbers of sellers are greater. However the incentive to innovate may level off or fall as the concentration falls further, as the firms may fail to internalise the return from their innovations for a longer period if the number of competitors become too large. This dynamic model also implies an inverted U-shape relationship between the concentration ratio and the research intensity.

Thus the effects of market concentration as well as the market share of the firm on the R&D-intensity are ambiguous.

Most of the empirical studies have reported a positive correlation between concentration and research intensity, see Scherer & Ross (1990), Scott (1984), Levin et al. (1985), Wahlroos & Backström (1982) and Lunn & Martin (1986). To test if there is an inverted U-relationship between concentration and research intensity, the theoretical models suggest the concentration measure should be entered non-linearly. There is some evidence of an inverted U-relationship with maximum research intensity at a four-firm concentration ratio of 50-60%, suggesting that industries neither should be too atomistic nor too monopolistic in order to support R&D spending. However, these results depend on whether the empirical analyses are based on industry level cross-section data or on pooled time-series and cross-section data. In the latter case, when controlling for unobserved heterogeneity, the inverted U-hypothesis typically fails to gain support.[1] The relationship may also differ across sectors. Lunn & Martin (1986) found a positive effect from the market share on the research intensity in the low-tech sector but no effect in the high-tech sector.

2.2. Firm size

In his work on innovation, Schumpeter focused much more on the absolute ***size*** of the firm than the concentration of the market, see above. If larger firms are more innovative, one would expect a positive relationship between firm size and research intensity, as noted by Lunn & Martin (1986), who tested this version of the Schumpeterian hypothesis on US line of business data including a variable for the total asset invested. They found a significant positive coefficient indicating that large firms use more resources on R&D per dollar of sales, especially within the high tech industries. This result is in accordance with Cohen & Klepper (1996) who find that the firms R&D expenditure increase more than proportionately with increasing firm size. On the other hand Vossen (1998), using Dutch data, finds that among firms that have decided to invest in R&D larger the firm size leads to higher R&D intensity. Førre (1997) gets a similar result for Norwegian firms except for the very large firms. Still, in both studies the probability of investing in R&D depends positively on firm size.

2.3. Profitability and R&D

According to Lunn & Martin (1986) a positive effect of profitability on research intensity should be expected. Using a model of profit maximising it is shown that the first-order conditions with respect to R&D are familiar to the Dorfman-Steiner condition of the amount of advertising, i.e. it pays to increase the R&D effort the more profitable is the marginal sale. Thus a positive relation between the price-cost margin and the research intensity is expected.

[1] See Levin et al. (1985).

Imperfect capital markets have often been mentioned as another reason for positive correlation (the liquidity constraint hypothesis). As research and development is an intangible asset it is difficult to raise external funding and therefore it has to be financed through retained earnings. In this respect profitable firms have better opportunities. However, according to Leibenstein's X-inefficiency theory, big firms in concentrated industries have the means, but lack the incentive to innovate.

Empirical analyses of the liquidity constraint hypothesis have typically included the cost-price margin or a similar measure of profit as explanatory variables in the R&D equation. However it seems that a more correct measure of the ability to finance R&D-investments by using internal funds would be the debt/assets ratio of the firm, or alternatively the financial solvency of the firm. A high financial solvency could in principle make it possible to finance R&D investments without borrowing funds at all. Or put it another way, if the firm has a low debt/equity ratio borrowing funds will probably be easier and at more favourable conditions than else. Further, as noticed by Niininen (1997) firms may prefer internal finance in high-risk investments like R&D, see also Hall (1992). Accordingly the expected impact of the solvency of the firm on the R&D-intensity is positive.

Returning to the effects of profitability Kamian & Schwartz (1982), Lunn & Martin (1986) argue that the effect on the R&D-intensity could be the reverse. If the firm operates in a competitive market with tough price competition, accordingly having low profits, it may have a higher incentive to use R&D as a product differentiating strategy. In that situation the impacts of profitability on the R&D-intensity would be negative.

The empirical evidence regarding the effects of profitability is somewhat mixed, however. Lunn and Martin (1986) found a significant negative effect of profitability on the R&D intensity that was especially strong in a sub-sample of high-tech industries. On the other hand Niininen (1997) finds that the financial position of the firm does affect the volume of its R&D investments significantly. More long-term debt decreases R&D investments, whereas a high cash flow stimulates R&D investments.

2.4. Demand conditions and R&D

Demand conditions are important for several reasons. According to Lunn & Martin (1986), Schmokler (1966) the firm will allocate R&D resources towards growing markets. Thus expecting high pay-off from those markets will induce the firm to make larger R&D investments. Therefore a positive relationship between industry sales growth and firm R&D intensity is expected.

Further, Lunn & Martin argue that industry output should be divided into shares going to consumer markets, to the local government and to the central government, the latter expected to be less "susceptible to differentiation, all else equal".

Backström & Wahlroos (1982) and Lunn & Martin (1986) discuss the influence from international trade. A higher export share may lead to an increase in the research intensity as the market increases and with it the return from an innovation. The effect from the import penetration, on the other hand, is unclear. A higher import share reduces the concentration in the market and may therefore have a negative effect on the R&D-intensity. However, more price competition may turn the firm's attention towards other means of competition such as research and development in new products.

In Farber (1981) the influence of the buyer concentration on R&D is discussed. If the bargaining power of the buyers of the product of the innovative firm increase the potential rent from its investment in R&D which accruing to the innovating firm itself might decline. Thus high degrees of buyers concentration are expected to affect the R&D-intensity negatively.

Wahlroos & Backström (1982) analyse the effects of import penetration and find a stable positive influence on the R&D intensity from the import/sales ratio, whereas Martin & Lunn (1986) detect only a weak negative relationship. In general Lunn & Martin (1986) find no influence from market growth. On the other hand the influence from the export ratio is positive and significant, the same is the case for a number of variables dividing the market into different segments. Finally it should be noted that the effects from related markets are ambiguous. Buyer concentration has no influence, whereas sales concentration in buying markets has an unstable effect depending on which sample they analyse (low- versus high-technological firms).

2.5. The source of financing and R&D

A number of studies pay attention to whether the productive effect of company financed R&D is higher than the correspondingly publicly financed R&D capital. According to Griliches (1980) lower productivity of publicly financed R&D investments may be due to externalities and restrictions on the appropriability of innovations. Further publicly financed R&D investments may have an indirect (positive) influence on the productivity of company financed R&D investments. As a consequence company financed R&D is expected to be higher compared to a situation without publicly financing of R&D.

In general a complete model should include variables to take account of externally financed R&D investments (from other firms within the same company, foundations, public funds etc.). The decision to start investing at all into R&D is expected to be positively correlated with the intensity or availability of some kind of external support. Moreover, the amount invested by the company itself might be positively correlated with the amount of publicly financed R&D.

Scott (1984) tests to what extent government and company financed R&D investments are either substitutes or complements to each other using US FTC-data for 3388 lines of business in 437 companies for 1974. The analyses reject the substitution hypothesis. Further, the model clearly suggests that publicly financed R&D investments stimulate company financed R&D investments. Levy (1990) finds a negative impact of government R&D in some US industries. Quellec & Ioannidis (1997) find a positive long-term relationship between government and privately funded R&D, using a panel of 6 industrialised countries. Further Niininen (1997) demonstrate that both direct subsidies and loans have a positive effect on R&D investments.[2]

2.6.Technical entry barriers and other factors.

In industries with a high ***minimum efficient scale*** (MES) or a high ***capital requirement*** new entries are already impeded and the existing firms may have less incentive to invest in R&D as a competitive strategy. Barriers to entry may therefore have a negative effect on the research intensity, as noted by Comanor (1967) Lunn & Martin (1986). However the empirical evidence is ambiguous. Lunn & Martin (1986) do not detect any significant influence from technical entry barriers, whereas Wahlroos & Backstrøm (1982) find a stable negative and significant effect of MES on the R&D intensity.

The influence of ownership should be mentioned. As was noted earlier the pay off to risky R&D-investments normally shows up in the longer run, which can be an effective barrier against investments for smaller firms. A familiar argument can be used for personally owned firms. Risk aversion and long pay off time may prevent such firms from undertaking of what is considered risky investments. For that reason LTD's are expected to use more resources on R&D than is the case for other types of ownership's (which mainly are personally owned firms). On the other hand if the number of shareholders become large the relative strength of the firm managers increases and they might be tempted to substitute long run profit/R&D investments today for short run profits. In that case LTD's would use fewer resources on R&D than else. Finally Baldwin (1995) argues that new established firms might be relatively innovative because they often have a large growth potential.

[2] See Capron & van Pottelsberghe de la Potterie (1997) for a survey over impact studies of public R&D sub-idies.

2.7. Some empirical problems

A particular problem in the empirical studies is the endogeneity of the market structure as the causality between the R&D-intensity and various measures of the competitive conditions can be the reverse. In general, the payoff to the firm from investment in research and development yields some advantages compared to its competitors, and in the end this may lead to an increase in firm size, market share and finally market concentration. A number of studies have taken this into account and using simultaneous estimation techniques, but without a marked impact on the estimated coefficients.

Another problem is that the technological opportunities vary a lot across industries. As a rule controlling for unobserved heterogeneity reduces the estimated impact of market structure variables. The reason is a high correlation between these technical opportunities and the market concentration and so they are not easy to disentangle and they may be jointly determined.

3. The empirical model

Most previous empirical studies estimate equations, in which the research intensity is regressed on a number of variables characterising the firm and its market conditions, see above. Estimations are based on either industry data or on firm/line of business data, e.g. see Wahlroos & Backström (1982) who uses data for 87 4-digit industries in Finland, Lunn & Martin (1986) who use 2297 line of business for 424 firms in 218 US industries or Niininen (1997) who use an unbalanced panel of 134 firms over a 5 year period.

In this study firm level data as well as data at the industry level are used. Focusing on the latter type of model - performing the analysis at the industry level - the R&D expenditure is zero in a number of industries. As a consequence OLS regression analysis with R&D intensity as the left hand side variable is inappropriate partly because the linearity assumption is not fulfilled but more importantly because the independent variable of the regression analysis is censored, i.e. nonnegative. The standard solution to this problem is to formulate a Tobit model, (Amemiya (1984)), as follows:

(1)
$$\begin{aligned} y_i^* &= x_i' b + u_i, \qquad i = 1,2,\ldots,n, \\ y_i &= y_i^* \quad if \quad y_i^* > 0, \\ &= 0 \quad if \quad y_i^* \leq 0, \end{aligned}$$

where y corresponds to the R&D intensity and x is a vector of explanatory variables. The error term u_i is assumed to be normal distributed with zero mean.

The likelihood function of (2) becomes

(2) $$L = \prod_{0} [1-\Phi(x_i' b/s)] \prod_{1} s^{-1} j [(y_i - x_i' b)/s]$$

where Φ and φ are the cumulative distribution and density function of the standard normal variable.

Turning to the analysis at the firm level it is assumed that each firm first decides whether to invest in R&D or not. Second if the firm does invest in R&D, how much of its resources should it decide to spend on R&D? As R&D investments will influence a company's annual result just like investments in fixed assets a decision to invest in the current period will reduce the current profits in return for an expected increase in future profits. However as compared to investments in 'normal' capital goods the return from investment in R&D capital is more uncertain and as a result the expected margin has to exceed some kind of reservation level before it invests in R&D-capital at all. Further there might be initial fixed costs when starting to invest in R&D.

Consequently, a decision to start investing in R&D will be taken together with the company's other investments so that the volume of investments is determined in a simultaneous system in which also profits, turnover and other central economic variables are determined at the same time. Because many of the companies have indicated that they do not have R&D expenditures, control for potential sample selection bias is needed, when trying to estimate models for the volume of R&D investment.

The problem with sample selection in R&D models can be illustrated in the following model, where R&D intensity is the variable to be explained and X as noted above is a matrix of explanatory variables. However, investing in R&D will only take place if a relevant set of variables, z*, is above a threshold. Formally, the model can be described as

(3) $$y = \beta \mathbf{X} + \varepsilon$$

(4) $$z^* = \alpha \mathbf{V} + u$$

If the value of z^* is above the threshold, model (3) can be estimated as a traditional OLS model. The problem with (4) is that the variable z^* is not observable. Instead the variable z is determined by

(5) $$z = 1 \text{ if } z^* > 0$$

(6) $$z = 0 \text{ if } z^* \leq 0$$

Here the value of *z* equals 1 if the firm is investing in R&D, that is, the threshold-value is exceeded. Focusing on firms actual investment in R&D, the expected value of R&D investments for firms with positive R&D investments is:

(7) $$E[y_i \mid x_i \text{ in sample}] = E[y_i \mid x_i, z = 1] = E[y_i \mid x_i, \alpha v_i + u_i > 0]$$

Assuming a bivariate normal distribution for the residuals, model (7) can be reformulated to

(8) $$E[y_i \mid x_i \text{ in sample}] = \beta x_i + \theta\lambda_i$$

where $\lambda_i = \phi(\alpha v_i)/\Phi(\alpha v_i)$. Model (8) can be estimated by Heckman's (1976, 1979) two stage method ('Heckit'-method). First, use a probit model for *z* to estimate the parameters in (4) and calculate λ_i for each firm. Second, the model in (8) can be estimated directly by OLS using the estimated λ_i.

4. Data

The data used in this study are based on public information on the economic performance of Danish firms and on a unique data set containing - in principle - all R&D-investments in Danish firms.

The general information on economic performance of firms comes from data from a private company (*Købmandsstandens Oplysningsbureau LTD.*). The basic source of information is firm-specific information on economic performance derived from firm's legal obligation to publish reports to the authorities. [3] All firm's data on economic performance are converted to calendar year accounts and all firms have been assigned an industry code corresponding to the Nace-code classification. Industry level data are constructed by aggregation of the firm-specific information in each industry. The sample used in this paper uses economic performance from 1995.

The data on R&D are obtained from the official Danish R&D statistics which are collected every second year by the Danish Institute for Studies in Research and Research Policy.[4] At the empirical level the concept of R&D comprises *creative work undertaken on a systematic basis in order to increase the stock of knowledge of man and society, and the use of this stock in order to devise new applications*; see the Frascati-manual p. 29. Further, R&D includes basic research, applied research and experimental development. The statistics on R&D within the private industries

[3] For a description of the account data, see Dilling-Hansen et al. (1997).

[4] Until the 1995-issue The Danish Ministry of Education and The Danish Ministry of Research were responsible for providing the data and for the publishing of the statistics.

cover firms within all main private sectors, i.e. ‘Agriculture, Forestry, Fishing and Mining’, ‘Manufacturing industry’, ‘Other industries’ (including services) and ‘Technological services’ as a special category. The basic reporting unit of the survey is the legal firm unit.

Firms of a certain minimum size, measured in terms of full-time employees, are automatically included in the survey (the minimum size varies across industries, but it is 90-100 employees for the most of the industries). The sample is augmented with 10% of the manufacturing firms having a smaller size than the minimum size just mentioned, i.e. typically firms with between 6 and 90 full-time employees.

In the 1995-survey the number of respondents was 2485. 2019 firms returned the questionnaire, giving a response rate of 81%. Of these 684 firms reported having positive R&D expenditure.[5] The questionnaire gives information on the R&D personnel, the intra- and extramural R&D expenditure, R&D expenditure by source of funding plus other information, see The Danish Ministry of Research (1997).

The data set is constructed by merging the account data with the R&D data. The account data are available at the firm level for each year since 1990. The overall data set on R&D, which are biannual, cover the period 1983-1995.

Table 1 gives a summary description of the basic data to be used in the empirical analyses. In the following brief description of variables used in the regression analysis a bracket with ‘I’ inside denotes that the particular variable relates to the industry level, an ‘F’ at the firm level.

R&D intensity (I,F) is defined as the company financed R&D expenditure in per cent of net sales and *Externally funded R&D* (I,F) is externally financed R&D expenditure (from public sources, foundations, other firms etc.) in per cent of net sales. *Rent* (I,F) is the ratio of net profits to net capital and *financial solvency* (I,F) is the ratio of net capital to total assets. *Minimum efficient scale* (I) is operationalized as the log 1st decile-value of firm sales in each industry. *Market concentration* (I) is measured as the standard Herfindahl index, based on firm sales. This is also the case for the *market share* (F), which is firm sales in percent of industry sales. *Size of firm* is measured either as log of total assets (F) or log of the number of employees. *Age of firm* (F) is measured as the number of years since establishment. The *export rate* (I) is the value of industry' export in per cent of total industry output. The *import rate* (I) is defined as import from foreign industries in percent of output from similar domestic industries plus the import itself. *Shipment to other industries* (I) is the sum of shipments to the 4 largest buying industries in percent of shipments

[5] See The Danish Ministry of Research (1997) for more detailed information on the statistics.

to all other industries. Finally market growth is measured by the *growth rate of industry sales* (I). In addition dummy variables are used in order to control for type of *ownership (F), external funding of R&D* (F) and for *public funding of firm R&D* (F).

Table 1. *Simple statistics of the merged data set, R&D- and account data, 1995.*

Variables	Number of observations	Mean	Standard dev.
Firm specific variables:	*(firms)*		
Annual turnover (DKK million)	1359	497.7	1764.5
Net capital (DKK million)	1917	166.2	1145.3
Number of Employees	1890	251	813
Rent (DKK million)	1917	22.7	163.6
Market share (%)	1359	13.8	22.1
Company-financed R&D intensity (%)	1337	1.7	6.3
Externally financed R&D intensity (%)	1337	0.6	0.5
Industry specific variables:	*(industries)*		
Herfindahl index of sales concentration	540	43.2	32.4
Import rate (%)	589	26.5	23.0
Export rate (%)	589	26.7	23.7
Shipments to other industries (%)	589	42.1	25.7
4-digit industry minimum efficient scale (log to 1st decile of firm sale in industry)	516	6.1	0.7

5. Empirical results

5.1. Regression analysis using industry level data

In this section the results of the analysis using industry level data from 1993 and 1995 are presented. The period 1993 to 1995 can be characterised as a period of improving business conditions, i.e. the average annual growth rate in real GDP rose from 1.5% p.a. to 2.6% p.a.

In general, the model in equation (1) is estimated at the 4-digit NACE-level. The model is estimated on industry data for the manufacturing-, building and construction-,trade- and transport-, communication-, financial- and other business service sectors. Not included industries are the primary sector, supply of water and electricity, hotels and restaurants and service industries having a NACE-code above 8000. The final sample includes about 284 4-digit industries.[6] The results are given in Tables 2-3.[7]

Table 2 gives the results of various versions of the model. The first column indicates that the simple inverted-U relation between the company-financed R&D expenditure and the market concentration is statistically significant. The value of the Herfindahl index, which gives the maximum R&D intensity, is calculated to be close to 55 per cent. This result is in accordance with a vast number of studies, see e.g. Scott (1984) who uses a similar model for 3388 US-manufacturing line of businesses and reaches maximum level for R&D intensity at the CR4-level of 64 per cent. In addition Levin et al. (1985) also find a strong support for the inverted-U hypothesis (using US-LB-data), with the maximum R&D sales ratio occurring at a CR4-level of 52 per cent.

However, when controlling for 4-digit industry fixed effects, initial experiments (not shown) were not in favour of the inverted-U hypothesis and the estimated coefficients of the simple equation were reduced considerably and lost their significance. Again this result is in accordance with Scott (1984).[8]

The second column includes the effect of externally funded R&D expenditure. The results clearly indicate that externally funded R&D expenditure is a complement to company-financed R&D expenditure. The estimated parameters are highly significant also in the models in columns 3 and 4.

Column 3 includes the rent variable, resulting in a negative and highly significant coefficient, implying. Thus higher profits seems to lower the R&D intensity. Accordingly our results do not support the liquidity constraint hypothesis of R&D. However, as noted by Lunn & Martin (1986) who obtained similar results for US industries the negative relationship does confirm the importance of conventional price competition as a spur to innovation, especially when the technological base exist to support innovation'. The result is also in accordance with the X-inefficiency theory.

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[6] The computations have been done using the Lifereg procedure in SAS.

[7] Estimating the model on industry level data is equivalent to analysing average behaviour. Therefore, the funcional form in this section is the Tobit formulation as opposed to firm level estimations which express individual behaviour. Accordingly Heckmans 2stage procedure has been chosen in the latter case.

[8] In order to deal with simultaniety problems between R&D expenditure and market structure, 2SLS regressions were made in the initial experiments. However, experiments with 2SLS procedures in order to control for the endogeneity of the concentration and profitability had only little or minor effects on the parameters.

Table 2. *Tobit models of the R&D intensity. Dependent variable: Company-financed R&D expenditure in per cent of turnover. Sample: 284 industries, 1993, 1995 (pooled data).*

	Basic model	Source of funding incl.	Rent included	MES, financial solvency incl.	Complete model
Intercept	8.9104 (3.5512)	8.5439 (3.3302)	9.1513 (3.300)	33.044 (14.920)	47.404 (15.578)
Dummy variable for 1995	-3.3227 (2.5745)	-2.5008 (2.4150)	-2.0512 (2.3917)	-1.9245 (2.3824)	-2.5923 (2.3928)
Externally funded R&D		1.8011*** (0.2815)	1.5725*** (0.2884)	1.5197*** (0.2884)	1.4927*** (0.2878)
Rent			-0.1101** (0.0359)	-0.1002*** (0.0365)	-0.0926*** (0.0364)
Financial solvency				-0.1261 (0.0817)	-0.0539 (0.0843)
Minimum efficient scale				-3.2688 (2.3581)	-2.0211 (2.3857)
Market concentration	0.4735*** (0.1772)	0.3833** (0.1664)	0.3900** (0.1648)	0.3962** (0.1651)	0.4646*** (0.1678)
Market concentration squared	-0.0041** (0.0017)	-0.0033** (0.0016)	-0.0034** (0.0015)	-0.0033** (0.0016)	-0.0038** (00016)
Export rate					0.0839 (0.0702)
Import rate					-0.3892*** (0.0886)
Shipment to other industries					-0.2301*** (0.0659)
Normal scale parameter	27.309 (1.025)	26.639 (0.9668)	25.323 (0.9545)	25.176 (0.9493)	24.973 (0.9461)
Log likelihood	-1704	-1685	-1681	-1677	-1665
Number of observations (non censored)	568 338	568 338	568 338	568 338	565 338

Notes: Numbers in brackets are standard errors of the estimated parameters. *** indicates that the estimated parameter differs significantly from zero at the 1% level of significance, ** at the 5% level and * at the 10% level.

In the 4th column minimum efficient scale, capturing barriers of entry, is introduced. The coefficient to MES is negative but insignificant. The result - that the research intensity is reduced but insignificant - when entry is more difficult is in accordance with Lunn & Martin (1986) who also find a non-significant effect of MES analysing US industries, but differs from the result of Wahlroos &

Backström's (1982) who finds a negative and significant effect in their analyses of 87 Finnish industries

The fifth column introduces a number of demand-related variables. The export and import ratios add information concerning sellers' concentration or the total market for the output from the industry. The import rate has a negative significant sign suggesting that import penetration lowers R&D. The influence from export is positive however insignificant.

Variables picking up the bargaining power of buyers are also introduced. The share of total sales directly to other industries (raw materials and intermediate goods), it has a significant negative coefficient, as expected. As discussed above, it should be expected that relative large sales to other industries increase the buyers' bargaining power compared a situation with relative large sales directly on the consumer market. The estimated parameter is in favour of this point of view.

Finally, it should be noted that nearly 60% of the observations on R&D are positive. The estimated coefficients of the concentration variable are fairly robust to the inclusion of other explanatory variables. Accordingly, table 2 gives support to the inverted-U hypothesis.

Table 3 displays the results of the full model estimated on three sub-samples of industries. The first columns divide the industries into high- and low-tech industries. High-tech industries are defined as industries belonging to the upper quartile with respect to the R&D intensity.[9]

The effect of market concentration has declined compared to results of table 2. Even though the estimated parameters carry the expected signs for high- as well as low-tech industries they are insignificant in both cases. Especially for low-tech industries market concentrations seems to be of no importance.

The effect of the minimum efficient scale is significantly negative for high tech industries alone whereas the influence of rent is negative significant for both types of industries. The demand variables seem to be more important in the high tech sample, e.g. with higher export rate follows higher R&D intensity.

Finally it should be noted that the parameter for externally funded R&D is positive and significant (and nearly equal) in both sub-samples.

Table 3. *Tobit models of company-financed R&D expenditure in per cent of turnover. Sample: Industries in 1993, 1995 (pooled data).*

	Low-tech sample	High-tech sample [a]	Manufacturing industries
Intercept	0.2007 (0.2338)	120.9 (42.66)	6.3288 (17.11)
Dummy variable for 1995	-0.0318 (0.0372)	-3.8755 (5.9373)	-4.005* (2.2546)
Externally funded R&D	1.0228*** (0.1884)	0.9592** (0.4588)	2.6275*** (0.9864)
Rent	-0.0010** (0.0005)	-0.2373** (0.1154)	0.0212 (0.0342)
Financial solvency	0.0030** (0.0012)	-0.3136 (0.2415)	-0.0751 (0.0809)
Minimum efficient scale	0.0141 (0.0353)	-12.02* (6.966)	-2.005 (2.491)
Market concentration	0.0015 (0.0027)	0.6739 (0.4224)	0.4431*** (0.1708)
Market concentration squared	$-3.78*10^{-6}$ $(2.60*10^{-4})$	-0.0055 (0.0040)	-0.0036** (0.0015)
Export rate	0.0012 (0.0010)	0.7648*** (0.2215)	-0.0116 (0.0677)
Import rate	-0.0003 (0.0013)	-1.0264*** (0.2746)	0.1456 (0.1170)
Shipment to other industries (per cent of total sales)	-0.0010 (0.0009)	-0.5737*** (0.2077)	0.1311 (0.0844)
Normal scale parameter	0.2919 (0.0135)	34.89 (2.070)	20.01 (0.8604)
Log likelihood	-83.4	-705.9	-1232.2
Number of observations (non censored)	424 196	142 142	423 196

Notes: Numbers in brackets are standard errors of the estimated parameters. *** indicates that the estimated parameter is significantly different from zero at the 1% level of significance, ** at the 5% level and * at the 10% level.

[a] The high-tech sample does not include any industries without positive expenditure on R&D. Accordingly, the parameters are identical to OLS-estimates.

Estimations were also carried out for the manufacturing industry only. Compared to the results presented in column 4 in table 2, the general impression is that the level of significance is lower for the manufacturing sample of industries. However it is worth noting that influence from the market

[9] The division into high- and low-tech industries is in line with Lunn & Martin (1986).

concentration on the R&D intensity is in line with the inverted U-hypothesis.[10] Finally it should be noted that the influence of externally funded R&D expenditure is positive and significant and seems more important than is the case for other industries.[11]

5.2. Regression analysis using firm level data

In table 4 various probit models for company financed expenditures on R&D are set out. If the firm has positive company financed expenditures on R&D the dependent variable is equal to 1, and zero otherwise.

The first column reports the results of a simple Schumpetarian model. The firm size variable turns out highly significant with a positive sign. Thus the simple model supports the weak Schumpetarian hypothesis, that larger firms are more likely participants in R&D. Next, looking at column 2 the results indicate that a higher market share reinforces the size effect, giving evidence to the Dorfmann-Steiner argument of the importance of the absolute market position.

In the third column the influences from profitability and financial constraints are introduced. First financial solvency has a significant and stable positive effect on the decision to use resources on R&D. That result is in line with the findings of e.g. Niininen (1997). Further-more, higher rent seem to provide less incentives to invest in R&D, which is in accordance with e.g. Lunn & Martin (1986). However the parameter vanishes and becomes insignificant in the complete model as more explanatory variables are introduced. In column 4 external funding of R&D is introduced. In general external funding of R&D stimulates the incentive to use own resources on R&D. In addition there is an indication of a larger effect of publicly funded R&D.[12]

[10] The inverted-U has its peak at a value of the Herfindahl-index close to 60%.

[11] Fixed effect estimations were tried in order to control for unobserved industry characteristics, i.e. technological oppportunities or managerial skills. The estimations (not shown) suggest that externally funded R&D expenditures still have a significant, positive effect on company-financed R&D, and the same is the case for minimum efficient scale and rent. However, the influence of market structure vanishes. For low-tech industries - alone - the opposite result is obtained. The inverted-U is highly significant, and the maximum value for the R&D intensity is reached at a market concentration level of 59%. In addition, the influence of externally funded R&D is still positively significant. Finally, it should be mentioned that the results for the high-tech sample indicate that there are negative significant effects of the rent variable, minimum efficient scale and financial solvency.

[12] Experiments were carried out in order to deal with the potential problem of simultaniety between company funded and externally/publicly funded R&D. However substituting the dummy variables for externally/publicly funded R&D with corresponding variables for 1993, using a smaller panel of firms covering 1993 and 1995, did not alter the estimation results noteworthy. As a consequence including a dummy variable for receiving public funding R&D in both years also gave a significant positive parameter. However the level of significance decreased for some of the other variables.

Table 4. *Probit model of company financed R&D expenditures, 1995. (1=positive R&D expenditures, else 0).*

	Schump etarian Models	Market share included	Financial con-straints incl.	Source of funding incl.	Complete model
Intercept	-2.3749 (0.0213)	-1.6728 (0.3021)	-2.2010 (0.3571)	-1.9072 (0.3875)	-3.4190 (0.4649)
Firm size (log total assets)	0.1602*** (0.0187)	0.0919*** (0.0274)	0.0894*** (0.0277)	0.0495* (0.0300)	0.0933*** (0.0334)
Market share (log)		0.0777*** (0.0269)	0.0751*** (0.0272)	0.1148*** (0.0293)	0.0423 (0.0333)
Financial solvency (log)			0.1698*** (0.0583)	0.1423** (0.0622)	0.1104** (0.0639)
Rent			-0.0009*** (0.0006)	-0.0010 (0.0006)	-0.0005 (0.0006)
Publicly funded R&D yes=1, else 0.				2.501*** (0.2540)	2.6288*** (0.2741)
Dummy for other externally funded R&D, yes=1, else 0				2.22269*** (0.3865)	2.1750*** (0.4171)
Ownership. 1=ltd, else 0.					0.7934*** (0.2086)
Dummy for manufacturing					0.2534** (0.1161)
Import rate					0.0081*** (0.030)
Export rate					0.0010 (0.0028)
Pearson χ^2-test (Goodness of fit)	1749.7 (P<0.497)	1253.6 (P<0.395)	1257.2 (P<0.353)	1200.0 (P<0.298)	1208.2 (P<0.673)
Log likelihood	-1012.4	-758.7	-753.8	-631.4	-598.9
Number of observations	1770	1252	1252	1252	1250

Notes: Numbers in brackets are standard errors of the estimated parameters. *** indicates that the estimated parameter differs significantly from zero at the 1% level of significance, ** at the 5% level and * at the 10% level. If the modelled probabilities fit the data the Pearson χ^2-statistics should be insignificant. Accordingly, a p-value equal to e.g. 0.492 (column 1) is strong evidence of a fairly good model fit.

The fifth column contains the full model that has been used to compute λ in the estimations below. Firms that are legal organised as limited liability companies have a higher probability of financing their R&D than other firms. The same holds for manufacturing firms and firms facing import competition. Turning to demand conditions the export rate is completely insignificant. On the other hand looking at the import rate the price-competition argument seems to be strongest resulting in a positive significant coefficient. This accords with the findings of Backström & Wahlroos (1982). Including sales growth was expected to result in a positive effect. However as in Lunn & Martin (1986) no significant effect was found.

In general the magnitude and significance level of the various parameters are fairly stable across different specifications.[13] Further, the overall test statistics indicate that the model fits the data well.

In addition to the reported statistics just mentioned fitted values were generated using the parameters in column 5. Comparing fitted and actual values a concordance of 78.2% is obtained.[14]

Table 5 presents the estimation results obtained by Heckman's two stage method. Thus the λ's derive from Table 4. In general the parameter for λ is significant indicating presence of selectivity effects.

The influence from firm size is analysed by including the number of employees. The result shown in column 1 suggest there is a weak negative influence on the R&D-intensity, see Vossen (1998) who get same result and Førre (1997). However experiments with the model revealed that this influence was mainly caused by the large firms (number of employees > 100), having less R&D in percentage of their sales. Accordingly this result does not support the hyphotesis of Schumpeter.

Market concentration has a significant positive influence on the R&D-intensity, which could be an indication of presence of non-price competition or non-collusive behaviour in concentrated markets.

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[13] Experiments were performed including lagged variables in order to deal with potenatial simultaniety problems. However substituting the firm size and market share variables with corresponding lagged values did not change the signs of the estimated parameters. But because these estimations were performed on a much smaller panel the level of significance in general decreased.

[14] In an earlier version of the paper estimations were performed on manufacturing firms, firms belonging to high- and low-tech. industries alone. The experiments for manufacturing firms indicate that especially Ltd.-companies and firms with an externally financed R&D programme tend to invest in R&D. A higher market share, financial solvency, minimum efficiency scale and degree of competition from imports, all tend to raise the probability of positive R&D-investments. On the other hand, higher rent tends to reduce the probability of investing in R&D. Firms in the high-tech industries do have a higher probability of investing in R&D but it seems that the decision on R&D-spending is very much determined in the same way as in other industries. The only difference between high-tech industries and the rest is that the influence of *rent* and *minimum efficient scale* becomes non-significant but still with the same sign of the coefficients.

Table 5. *OLS models including Heckman's l to avoid sample selection problems. Company financed R&D expenditure in per cent of turnover, 1995.*

	Basic model	Including concentration squared and firm size categorized	Complete model
Intercept	24.306	19.022	14.488
	(8.6509)	(8.6989)	(9.575)
Firm size (log number of employees)	-0.9485*	0.6090	0.7595
	(0.5441)	(0.6872)	(0.7071)
Dummy for large firms (1 if no. Of employees >100, else 0)		-5.5602***	-5.655***
		(1.6311)	(1.6420)
Market share (%)	-0.2045***	-0.2983***	-0.3055***
	(0.0757)	(0.1060)	(0.1065)
Market share squared	0.0012	0.0026*	0.0027*
	(0.0008)	(0.0014)	(0.0015)
Market concentration, Herfindahl index (%)	0.0844**	0.2000**	0.1958**
	(0.0405)	(0.977)	(0.0991)
Market concentration squared		-0.0019	-0.0018
		(0.0014)	(0.0014)
Minimum efficient scale (log 1st decile-value of sales in indust.)	-2.6459**	-2.6454**	-2.4495*
	(1.3355)	(1.3271)	(1.3850)
Rent (Net profit in percent of net capital)	-0.0440***	-0.0456***	-0.0443***
	(0.0106)	(0.0105)	(0.0106)
Financial solvency (Net capital in percent of total capital, log)	2.9784***	3.3617***	3.3002***
	(0.8643)	(0.8576)	(0.8821)
Externally funded R&D in percent of sales			0.1134
			(0.1490)
Age (log of years)	-1.7490***	-1.8044***	-1.8459***
	(0.5520)	(0.5446)	(0.5482)
Dummy for ownership Ltd=1), else 0.			2.8087
			(2.8941)
Dummy for manufacturing industries (1), else 0.	-3.8576***	-3.4284***	-4.9115**
	(1.1966)	(1.1939)	(2.0729)
Growth rate of industry sales, Percent			-0.0008
			(0.0011)
Dummy for import industry.1 if import rate > median rate (29.7%), else 0.			0.8703
			(2.0095)
Dummy for export industry 1 if export rate > median rate (33.2%), else 0.			1.1299
			(1.5019)
Heckman's λ	1.9869***		1.5038***
	(0.5676)		(0.5954)
Number of obs.	384	384	384
R^2 (adj.)	0.19	0.21	0.21

Notes: Numbers in brackets are standard errors of the estimated parameters. *** indicates that the estimated parameter differs significantly from zero at the 1% level of significance, ** at the 5% level and * at the 10% level.

Further, the estimations show that there is a stable and negative significant effect of market share and a less significant positive effect from market share squared on the volume of company financed R&D. The sign of the two parameters suggest an U-formed relationship with minimum values around 60%. Together with the positive sign of the concentration variable - shown in the next row - these results to some extent are in favour of the Schumpetarian hypothesis. Thus the dominating firms spend a relatively larger amount on R&D. However experiments with the model showed that the magnitude and significance of the squared term for the market share variable were highly unstable and in the estimations actually shown in table 5 the parameter is significant only at a 10% level. Accordingly there is strong evidence of a negative relationship between market share and the R&D-intensity over the relevant range of the market share variable, meaning that as the market power of the firm itself becomes larger the R&D effort becomes smaller.

The minimum efficient scale, which is included in the model in order to measure the effect of technical entry barriers, has a significant effect on the R&D intensity, suggesting that high entry barriers and investment in R&D are substitutes.

In table 4 it was demonstrated that the probit estimation did not give evidence in favour of any influence from firm age. However among firms actually investing in R&D the firms age has a highly significant negative effect on the R&D-intensity. Younger and new established firms normally do have a larger potential for growth and accordingly stronger incentive for investing in R&D, e.g. see Baldwin (1996).

On the other hand the effect from import (positive but insignificant) and the rent variable (negative and significant) is in accordance with the corresponding parameters from the probit model, see table 4. Thus if the firm is located within an industry having a relative high import rate competition is probably much stronger. As a consequence the firm uses more R&D as a parameter in its competition strategy. In addition lower rent can be seen as an indicator of a strong competitive environment. The firm will spend more resources on R&D in order to deal with its competitors.

Financial solvency has a positive influence on the R&D intensity. Higher solvency (or less debt) increases the R&D intensity. Further the results on the influence from external funding suggest that more external funds stimulate the firms' own contribution in financing R&D. However the parameter is not significant.[15]

[15] Including a variable for especially public funding of R&D did not give stable results. Thus some estimation forms gave a negative however insignificant prameter. In addition lagged dummy variable for public funding gave positive parameters but they were also insignificant. The main impression from the experiments is that externally and privately funded R&D to some extent are simultaneous. Thus more effective panels are needed in order to estimate e.g. equation systems to be conclusive on the long term stimulation effect of public funded R&D.

6. Conclusions

The estimated models explain the variation in the company financed R&D-intensity quite satisfactorily. According to *the estimations at industry-level* there is empirical evidence of positive effects of externally funded R&D. This influence is stable irrespective of dividing the sample into high- and low-technological industries.

Market concentration has a positive effect on the research intensity in Danish industries, but the effect levels off and falls in highly concentrated industries. This inverted-U relationship is very stable and significant across the different model specifications for the whole industry.

As the concentration of industries is different from the concentration of markets due to foreign trade, control were made for the import and export share in the industries. In general the control variables had no effect except for the high-tech sector, where the export share has a positive impact on the research intensity. This is in line with other results where the export share has a high positive and very significant effect on the research intensity in both high- and low-tech industries. Paying attention to other demand variables, there is some evidence that buyer concentration is of importance.

The minimum efficient scale has a negative effect on the research intensity for all industries. However the effect is significant only for the group of high technological industries and only weak. This means that the industry estimations gives only poor evidence for the proposition that in markets with high entry-barriers there is less investment in R&D.

Industry level profits have a negative effect, supporting the price-competition argument, whereas the parameter of financial solvency is positive, but insignificant except for the low-tech industries.

The probit estimations on *firm-level data* give highly significant parameters of the expected sign. The probability of investing in R&D increases with firm size and market share which is a weak indication of the ideas of Schumpeter. Further, stable and significant effects are found for the financial solvency of the firm, suggesting that financial constraints do have an effect on R&D investments.

As it is the case for estimations at the industry-level higher rent decreases the probability of investing in R&D again giving evidence to the price-competition argument. However the level of significance vanish as the model is extended. The estimations show that external funding in general has a positive effect and that there is an independent effect of public funding. Finally firms owned ad LTD's and firms within the manufacturing industry are more likely to invest in R&D.

Estimations of *the company financed R&D intensity* - for R&D investing firms - show that the larger firms do have lower R&D-intensity than other firms. The same is the case for older firms. Accordingly among the firms that actually invest in R&D the small and young firms have relatively high R&D expenditure measured as percent of their sales. Further the type of ownership (Ltd) has no effect on the magnitude of R&D once the firm has decided to invest in R&D.

The R&D-intensity increases with higher market concentration but decreases, as the firms own market share is growing. Thus oligopolistic market forms seems to induce more R&D in Denmark. However, as the firm itself becomes more dominant its R&D-effort becomes relatively smaller.

The estimations suggest that protection against entrants if form of high technical entry barriers (MES) lowers the R&D intensity.

Furthermore, higher financial solvency stimulates the R&D effort. The results for the effects of rent indicate that price competition induces R&D expenditures. The estimations were not in favour of the rent variable interpreted as a measure for cash flow.

Finally, the rate of externally funded R&D does have a positive effect on the research intensity. However the influence is weak and less clear-cut than for the estimations at the industry level. One explanation for this difference is that subsidising research and development makes more companies doing such activities. But for the firms already engaged in R&D, the external funding to some extent substitutes their own funding, hence reducing the overall influence. This is a normal problem with subsidies, which only has an effect at the margin.

References

Amemiya, T. (1984), 'Tobit Models: A Survey', *Journal of Econometrics* (24), p. 3-61.

Arrow, K. J. (1962), 'Economic Welfare and the Allocation of Resources for Invention', in NBER: *The Rate and Direction of Inventive Activity: Economic and Social Forces*. Princeton: Princeton University Press.

Baldwin, J.R. (1995), *'The Dynamics of Industrial Competition: A North American Perspective'*, Cambridge University Press.

Capron, H. and Van Pottelsberghe de la Potterie, B. (1997), 'Public Support to Business R&D: A Survey and some new quantitative Evidence' in OECD: *Policy Evaluation in Innovation and Technology - Towards best practice,* p.171-188.

Cohen, W.M., 1996, A Reprise of Size and R&D, *Economic Journal*, Vol.106 p.925-951.

Dilling-Hansen, M., Madsen, E. and Smith, V. (1997), 'Entry into Danish Manufacturing Industries', in: S. Laaksonen (ed.) *The Evolution of Firms and Industries,* p. 180-193, Statistics Finland.

Farber, S. (1981), 'Buyer Market Structure and R&D Effort: A Simultaneous Equations Model', *Review of Economic and Statistics,* Vol. 68, p. 336-345.

Førre, Svein Erik, *'Er store foretak mer forskningsintensive? En anvendelse av diagnostiske metoder*', Statistiscs Norway, Rapporter 97/11.

Guellec D. and Ioannidis, E. (1997), '*Causes of fluctuations in R&D expenditures - A quantitative analysis*', OECD, DSTI/EASD, mimeo 19 p.

Griliches, Z. (1980), 'Returns to R&D expenditures in the private sector', p. 419-454 in Kendrick, J. W. and Vaccara, B. N. *Conference in Economic Research in Income and Wealth: Studies in Income and Wealth, vol. 44. Chicago.*

Hall, B. (1992), *Investment and Research and Development at the firm level: Does the source of finance matter?*, NBER Working Paper no. 4096, Cambridge MA.

Heckman, J. (1976), 'The Common Structure of Statistical Models of Truncation, Sample Estimation for Such Models', *Annals of Economic and Social Measurement* (5), p. 475-492.

Heckman, J. (1979), 'Sample Bias as a Specification Error', *Econometrica* (47), p. 153-162.

Kamien, M. I. and Schwartz N. L. (1975), 'Market Structure and Innovation: A Survey'. *Journal of Economic Literature*, (13), 1-37.

Kamien, M. I. and Schwartz N. L. (1982), *Market Structure and Innovation*, Cambridge University Press.

Leibenstein, H. (1966), 'Allocative Efficiency vs. 'X-Efficiency''. *American Economic Review*, (56), p. 392-415.

Levin, R. C., Cohen W. M. and Mowery D. C. (1985), 'R&D Appropriability, Opportunity, and Market Structure: New Evidence on Some Schumpeterian Hypotheses'. *American Economic Review*, (75, 2), p. 20-24.

Levy, D. P. (1990), 'Estimating the impact of Government R&D, *Economic Letters*, Vol.32, p 169-173.

Lunn, J. and Martin S. (1986), 'Market Structure, Firm Structure, and Research and Development', *Quarterly Review of Economic and Business*, Vol. 26, p. 31-44.

The Danish Ministry of Research (1997), *Research and Development in the Business Sector in 1995*.

Needham, D. (1975), 'Market Structure and Firms' R & D Behaviour', *Journal of Industrial Economics*, (23), 241-55.

Niininen, P. (1997), 'Technology Subsidies, R&D Investment and Productivity', in Laaksonen, S., *The evolution of Firms and Industries, Research Reports 223, Statistics Finland*, p. 340-351

OECD (1993), *The Frascati Manual.*

OECD (1998), *The Stimulation Effect of Government Support to private R&D*, DSTI/EAS/ STP/NESTI discussion paper.

Scherer, F. M. (1967), 'Research and Development Allocation under Rivalry', *Quarterly Journal of Economics*, (71), 359-94.

Scherer F. M. and Ross, D. (1990), *Industrial Market Structure and Economic Performance*, Houghton Mifflin, Boston.

Scott, John T. (1984), Firm versus Industry Variability in R&D Intensity. In: Zvi Griliches (ed.) *R&D, Patents, and Productivity*. The University of Chicago Press, Chicago and London.

Schmockler J. (1966), *Invention and Economic Growth, Cambridge:* Harvard University Press.

Schumpeter, J. (1942), *Capitalism, Socialism and Democracy*. Harper & Row, 1942.

Vossen, R.W. (1998), *Strategic and tactical Decisions, sunk Costs and Firm Size Effects in R&D*, Research report, 98B19, SOM, University of Gronigen, 1998.

Wahlroos, B. and Backström M. (1982), 'R&D Intensity with Endogenous Concentration' Evidence, *Empirical Economics*, (7), 13-22.