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## Does location matter for firm R&D behaviour Some empirical evidence

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**Does location matter for firms' R&D behaviour?**

**Some empirical evidence.**

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**Abstract:** Taking inspiration from Kleinknecht and Poots (1992) survey this paper examines whether regional location matters for Danish firms' R&D performance. The urban hierarchy hypothesis is examined on the micro dataset obtained by merging Danish R&D statistics with account data. Both the logit analysis on the probability of firms undertaking R&D and tobit analysis on R&D intensities reveals that the R&D performances of firms located in urban agglomerations are greater than for firms elsewhere. Non-regional factors such as ownership (dependence), business sector and age have as well been estimated to have a significant influence on firms' R&D performance. In addition, the employment size of the firm only has a significant effect on the probability of firms undertaking R&D while the concentration ratio only significantly affects the R&D intensity. However, comparing the non-regional with the regional determinants, the non-regional determinants seem to be of more importance.

Keywords: R&D, Regions, Urban agglomerations

JEL Classification: O18, O31

## 1 Introduction

Throughout decades regional shifts in the structure of the industry towards larger concentrations of innovating firms in urban areas have been observed. The theoretical concept intended to account for these shifts is the urban hierarchy hypothesis. It is based on the lifecycle of industrial development (see e.g. Malechki's survey (1983)) and predicts that large urban agglomerations are advantageous environments for innovating firms. This owns to the presence of tertiary educational institutions and other research centres that provide access to a highly qualified labour force and knowledge. The physical proximity of business partners and other firms involved in research and development (R&D) also have an important influence on firms' R&D behaviour (see Kleinknecht and Poot (1992)).

Innovations are often associated with risks and uncertainties. In the early stage of their lifecycle, unforeseen technological problems, consumer reactions and/or actions by competitors may change a firm's market power position and the evolutionary direction of the innovation. It is therefore possible that access to knowledge is important for the emergence of innovations and the probability of their success. As research centres are often located in the Metropolitan area or in larger cities, it seems plausible that firms in these areas are more innovative given the advantages of agglomeration. In the later stages of an innovation's lifecycle the technology behind the innovation matures and becomes more standardized. The advantages of urban agglomeration may ease off due to new competitors that enter the market as they see a profitable business and thereby impair the market power of the innovating firm. This may cause the firm to transfer its production to rural areas where factor prices are lower (Markusen (1985)). Thus, if firms' location is of importance to their innovative behaviour, one can expect that firms located in urban agglomerations are more likely to be engaged in R&D and that their efforts in connection with R&D are more serious than similar firms located in rural areas (Malecki (1980)).

A firm's R&D effort is calculated as its R&D intensity and is defined as either

- 1) The sum of R&D man years as a percentage of all employees in firms which perform R&D activities, see Kleinknecht and Poot (1992) or
- 2) The sum of the R&D expenditures as a percentage of the turnovers of firms performing R&D, see Dilling-Hansen et. al. (1998).

The aim of this study is to empirically test the influence of regional location on the R&D behaviour of Danish firms. By merging and applying micro data from the Danish R&D statistics with account data, endeavours are made to explain the R&D probability of a firm and its R&D intensity, respectively, by means of deterministic relations that take into account both the location in relation to an urban area and other non-regional characteristics of the firm. The next section outlines and discusses the regional and non-regional determinants that are expected to have an affect on firms' R&D behaviour. Section three presents the micro data set used in the study and subsequently empirical results of the urban hierarchy hypothesis follow in section four. The final section concludes on the key findings of the study.

## **2 Regional and non-regional determinants**

The purpose of this study is to estimate the importance of firms' regional location for their R&D behaviour. Firms' R&D behaviour can be split into two: 1) the R&D probability that indicates how inclined firms with given characteristics are to be engaged in R&D; and 2) the R&D intensity that indicates the scale of effort devoted to R&D.

To estimate the influence of the regional environment on firms' R&D behaviour decisions have to be made on how to include regional location and which non-regional determinants to include, see e.g. Dilling-Hansen et al. (1998), Kleinknecht and Poot (1992) or Dixon and Seddighi (1996). The determinants expected to have an effect on firms' R&D behaviour are listed below

- Regional location
- Employment size of firms
- Profitability and competitiveness
- Concentration ratio
- Ownership characteristics (independent vs. part of a group of firms)
- Age of firms
- Solvency ratio
- Business sector (manufacturing vs. service industry)

## 2.1 Regional determinants

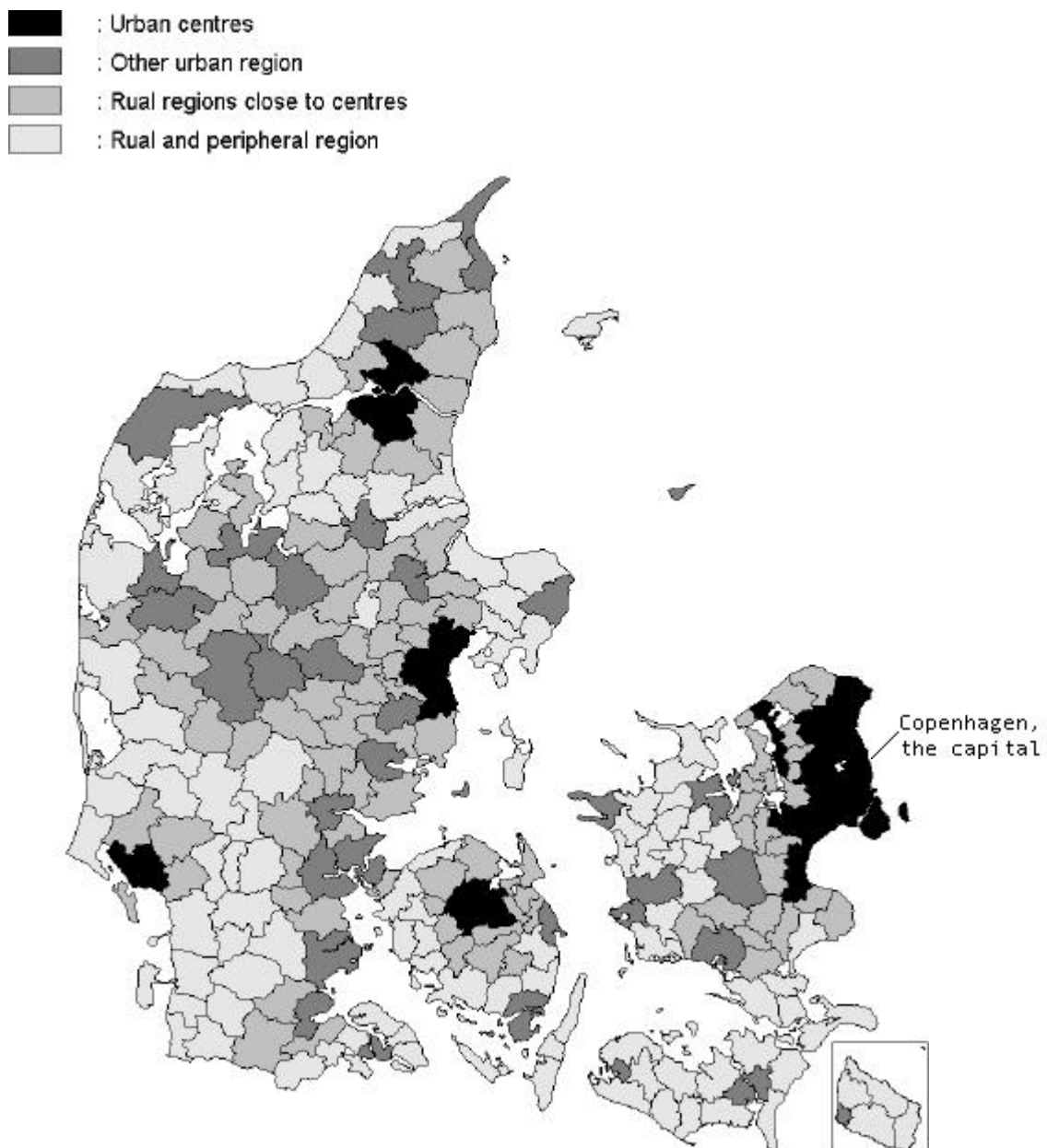
As mentioned in the introduction the urban hierarchy hypothesis assumes that the physical distance between the location of the firm and an urban area has an influence on the firm's R&D behaviour. The expectation is that firms located closer to urban areas are both more likely to be engaged in R&D and engage themselves more intensively in their R&D than firms farther away from an urban area.

In order to analyse the influence of a firm's location on its R&D behaviour in conformity with the urban hierarchy hypothesis all Danish municipalities are classified according to criteria listed below. The classifications take into account the physical size of each municipality in relation to employment, commuting intensity and the distance to an urban area.

- 1) *Urban centres*: Municipalities having more than 40,000 jobs and a commuting intensity (in-commuters relative to out-commuters) above 2.
- 2) *Other urban regions*: Municipalities with more than 10,000 jobs and located in the neighbourhood of an urban centre municipality though within 40 km from the urban centre (geographical midpoint).
- 3) *Rural regions close to centres*: Rural municipalities within a distance of less than 20 km from an urban centre municipality or municipalities within a distance of 15 km from a municipality in the classification: other urban region.
- 4) *Rural and peripheral regions*: Other rural municipalities not included in 3.

Figure 1 illustrates the subdivision of municipalities into the above listed classifications.

*Figure 1: Subdivision of The Danish municipalities*



Note: Regions categorized according to information from Institute of Local Government Studies - Denmark.

In accordance with the urban hierarchy hypothesis the expectation is that

- 1) Firms located in 'urban centres' are more likely to invest in R&D and engage themselves more intensively than firms located in 'other urban regions'.
- 2) Firms located in 'other urban regions' are more likely to invest in R&D and engage themselves more intensively than firms located in 'rural regions close to centres'.
- 3) Firms located in 'rural regions close to centres' are more likely to invest in R&D and

engage themselves more intensively than firms located in 'rural and peripheral regions'.

## **2.2 Non-regional determinants**

Large amounts of literatures based on Schumpeters (1942) two famous hypothesis anticipate that (1) the employment size of firms and (2) firms' market power are conducive to innovation.

### ***The employment size of firms***

The employment size of firms has by the literature been identified to have a significant influence on firms' R&D behaviour. By virtue of their employment size, larger firms are more capable of utilising large-scale production, marketing and financing and are for that reason ideal units for R&D. Thus, the expectation is that firms' R&D behaviour depends positively on their employment size. The relation is expected to diminish with employment size why the logarithmic to the numbers of employees will be used in the model.

### ***Profitability and competition***

A way to test how a firm's competitive environment influences their R&D behaviour is to include a measure of the firm's profitability. To incorporate the amount of the invested capital into a performance measure, returns on investments (ROI) has been used. ROI is defined as operating income relative to total assets. The interpretation is that higher ROI indicates lower use of total assets. According to Kamian & Schwartz (1982) (see also Lunn & Martin and Dilling-Hansen et al (1998)) firms that operate in competitive markets with tough price competition experience low earnings, and may for this reason have an incentive to invest in R&D in order to pursue a product differentiating strategy. Contrary, a monopolistic firm with high operating income may disregard potential innovative opportunities for product or production processes if effective barriers of entry exist. If no such barriers exist, seeing a profit making business entrants will try to enter the market and if entry is successful they will cause increasing competition. The stronger competition may then encourage firms to perform cost-reducing R&D, which thereby decreases ROI. The impact of profitability on firms' R&D behaviour is therefore expected to be negative<sup>1</sup>.

### ***Concentration ratio***

Another hypothesis put forward by Schmookler (1966) states that market demand measured by patent holdings has a significant affect on firms' innovative behaviour. Firms are expected to invest in growing markets and the optimistic expectation of future sales possibilities may result in more R&D. On the basis of the sample data a measure of the concentration ratio has been used to account for Schmooklers "demand-pull" argument. The concentration ratio is of the Herfindale-type and measures the square of a firm's turnover in relation to the total turnover of the business sector to which it belongs<sup>2</sup>. In line with other studies the expectation is that firms with either very high or low concentration ratios are less engaged in R&D than firms operating in markets in between. An inverted U-shaped functional relation between firms' R&D behaviour and their concentration ratio is therefore expected.

### ***Ownership characteristics (independent vs. part of a group of firms)***

Arguments that independent firms to a larger extent are forced to engage in R&D on their own to produce new knowledge and to implement the results in new innovations can be put forward, see Dilling-Hansen et. al. (1998). However, firms belonging to a group of firms have at their disposal more human resources and capital and may in addition have business associates that provide easier access to knowledge and financing. Firms belonging to a group of firms can as well better allow themselves to take risks. Thus, firms belonging to a group of firms are expected to perform more R&D than independent firms. This expectation is in accordance with Kleinknecht and Poot's (1992).

### ***Age of firms***

Newly established firms generally have a larger potential for growth and as a consequence have a stronger incentive for investing in R&D, see e.g. Baldwin (1996). Conversely, firms of a certain age might have better organizational and financial opportunities to gain from risky R&D investments. Thus, to account for the assumption that both the very young and old firms perform more R&D, the expectation is that firms' age has a U-like influence on the R&D behaviour. As age is expected to have a diminishing affect on R&D the logarithm to age is used.



### ***Solvency ratio***

Compared to investments in physical capital the payoffs of R&D investments are more risky and have expected payoffs in the far future. External investors may be reluctant to undertake risky investments and the firm may therefore find it difficult to raise capital for its R&D. That is, the firm face a liquidity constraint. The self-financing possibilities of the firm are often measured by its financial solvency i.e. equity capital as a percentage of total assets, which is the measure used to account for the liquidity constraint faced by the firm. Thus, having a high degree of financial solvency the firm is expected to face lower capital costs which is expected to have a positive influence on the R&D behaviour, see Dilling-Hansen et al (1998) for earlier Danish evidence.

### ***Business sector (manufacturing vs. service industry)***

In line with other studies, e.g. Kleinknecht and Poot (1992), the firms are divided into two groups, manufacturing- and service industry. The expectation is that the former are more engaged in R&D than the latter.

## **3 The Data**

The data to be used in the analysis concerns year 1997 and is derived from two different sources. First, general information on the economic performance of Danish firms is obtained from a private company (Købmandstandens OplysningsBureau), which collects and organizes firm specific information from the authorities to which all Danish firms have a legal obligation to report to. Second, data on R&D is drawn from the official Danish R&D-statistic, which since 1995 has been collected by The Danish Institute for Studies in Research and Research Policy.

The basic reporting unit is the legal firm. The sample consists of those firms that are registered in both statistical sources, nearly 1600 firms. However according to Table 1, there are only about 1300 firms with information on financial determinants. Statistics on non-regional determinants are represented in Table 1.

*Table 1: Statistic on non-regional determinants, 1997*

Determinants	Number of Observations	Mean	Standard deviation
Employment size	1576	208.7	917.4
Independent firms (1), else 0	1576	0.46	-
Manufacturing firms (1), else 0	1576	0.54	-
Age of firm	1576	25.4	37.8
Solvency ratio	1293	0.28	0.73
Concentration ratio	1568	0.23	0.21652
Profitability and competitiveness	1294	0.043315	0.181327
Assets (Dkk. 1,000)	1294	1,199.6	17,806.1

On average the employment size of firms is nearly 209 indicating that large firms are overly represented in the dataset. The standard deviation indicates likewise that the sample includes some very large firms. Furthermore, the average age of firms is 25.4, 46 percent of the included firms are independent firms and 54 percent belong to the manufacturing sector.

Table 2 places firms in the sample in the urbanization area to which they belong. Notable is the skewed distribution of firms' expenditures on R&D. Close to half of the firms engaged in R&D are located in an urban centre but invest for what amounts to almost 70% of the total expenditures on R&D in the business enterprise sector (BERD). The number of firms located in 'other urban regions' and 'rural regions close to centres' are greater than the number of firms located in 'rural and peripheral regions' even though firms located in 'rural and peripheral regions' stand for the second largest share of BERD. The explanation for this fact is the large amount of manufacturing firms located in 'rural and peripheral regions'. The R&D intensity is on average greatest for firms located in 'rural regions close to centres' followed by firms located in 'urban centres', 'rural and peripheral regions' and finally 'other urban regions'.

**Table 2: The share of BERD and R&D intensity of the urbanization regions, 1997**

Urbanization regions	Number of firms engaged in R&D	BERD (%)	R&D intensity (%)
Urban centres	433	69,6	6,51
Other urban regions	199	9,2	3,63
Rural regions close to centres	140	7,9	7,31
Rural and peripheral regions	126	13,4	5,59
Denmark, total/average	898	100,0	6,01

## 4 Results

This section presents results of analyses regarding determinants of firms' R&D probability and their R&D intensity. The first analysis examines which of the described determinants have a significant influence on the probability that Danish firms perform R&D, e.g. have an influence on firms decisions to perform R&D. Attention is paid particularly to whether firms' regional location is important for their decision. The second analysis focuses on whether firms' regional location is important for how intensively firms perform R&D. The non-regional determinants' influence on the R&D intensity is also examined.

### 4.1 Decisions to perform R&D

A firm's decision to perform R&D is measured as the probability that the firm is engaged in R&D. This R&D probability can be written as

$$(1) \quad L(w) = \frac{e^w}{1 + e^w}$$

$$(2) \quad w = x' \mathbf{b} + u$$

$w$  is the logarithm to the odds that the firm performs R&D.  $x$  is a column vector of regressors,  $\mathbf{b}$  is a column vector of regressor parameters and finally  $u$  is the error term with the assumption of 0 mean.

The logit model is a linear probability model where the dependent variable adopts value 1 when firms have positive R&D expenditures and 0 otherwise.  $w$  is a latent variable that indicates the expected probability given the included determinants. The logistic functional form is achieved by assuming the error term is logistically distributed. Table 3 presents the results of various logit models on R&D performance of Danish firms. First, the model is estimated with all determinants mentioned in section 2 and thereafter the model is reduced gradually. Model 2 and 3 are final models with respectively four and two regional dummies.

Model 2 indicates that the decision of a Danish firm to perform R&D is positively affected by the employment size of the firm, if the firm belongs to the manufacturing sector or if the firm belongs to a group of firms. These results are all in agreement with expectations and the variables are stable and persistently significant.

An examination of the variables 'age' and 'age squared' shows that a removal of one of the two leads to significance of the other at a 95% confidence level. The model fit remains at 70.4% while a removal of both variables leads to a fall in the model fit. Both variables are therefore kept in the model. The estimate of firm's age does not turn out to be significant because of multicollinearity. In Model 1, Table 3, firm's age affects the R&D probability as expected, e.g. the age of the firm has a U-shaped influence with a minimum probability of performing R&D at the age of 25. The U-shaped influence on the R&D probability is however not supported in Model 2 and 3 where older firms no longer are more likely to perform R&D. The influence of age on the R&D probability is greatest for newly established firms and decreases thereafter for older firms. In Model 5, Table 3, the significance of firm's age has also been tested on the 1286 observations of model 4 and by and large the model fit remained unchanged.

Three determinants were removed gradually from the model since their estimates neither could be proven significant or stable: profitability, financial solvency and the concentration ratio.

The influence of firms' regional location is examined proportional to 'urban centres', e.g. 'urban centres' act as the basic area. The estimated coefficients of the urban areas

indicate the departure of the likeliness of a firm performing R&D in relation to urban centres. With this a negative (positive) coefficient indicate that firms located in that area are less (more) likely to be engaged in R&D.

The two regional dummy variables that account for firms in 'other urban regions' and 'rural and peripheral regions' are both significant with negative signs. In accordance with the urban hierarchy hypothesis firms located in these regions are less likely to perform R&D than firms located in 'urban centres'. In addition, as the coefficient to 'rural and peripheral regions' is smaller than the coefficient to 'other urban regions' the urban hierarchy hypothesis is further supported. This is contrary to Kleinknecht and Poot's (1992) evidence on Dutch data. The coefficient to the last urbanization area, 'rural regions close to centres', is positive but insignificant in statistical sense. The coefficients of the regions are however not significantly different from each other for which reason regions have been reduced to two. 'Rural regions close to centres' and 'urban centres' have therefore been merged and the estimation results of the final model with only two regional dummies are presented in Model 3, Table 3. Evidence indicates that firms located in the merged region of 'urban centres' and 'rural regions close to centres' are more likely to perform R&D than firms elsewhere. The coefficient estimate of the dummy variable that accounts for firms located in 'other urban regions' and 'rural and peripheral regions' is significantly negative. A classification of the Danish counties into two urban regions appears appropriate and can be supported by the regional firm structure in Denmark where e.g. high-tech firms to a larger extent either move to or establish themselves in 'rural regions close to centres'. Denmark is moreover a small country, which results in rather small regions.

When all insignificant variables have been removed from the model, the model predicts the probability that firms perform R&D correctly in 70.4% of the cases. Hence, the conclusion is that the employment size of the firm, ownership, business sector and regional location are of significance for firms' decisions to perform R&D.

**Table 3: Logit models of the probability of firms conducting R&D Expenditures in 1997**

Determinants	Model 1	Model 2	Model 3
Intercept	-0,8831 (0,7291)	-1,2149 (0,5635)	-1,1972 (0,5624)
Log of employment size	0,3346*** (0,0514)	0,3104*** (0,0438)	0,3088*** (0,0437)
Dummy for independent firm	-0,3428** (0,1356)	-0,3442*** (0,1235)	-0,3399*** (0,1232)
Dummy for manufacturing firm	1,0031*** (0,1382)	0,8700*** (0,1181)	0,8863*** (0,1131)
Age (Log of firm's age)	-0,6481 (0,4792)	-0,1940 (0,3636)	-0,1961 (0,3640)
Age squared	0,0993 (0,0814)	0,0051 (0,0594)	0,0058 (0,0595)
Solvency Ratio	-0,0789 (0,0934)		
Concentration ratio (Herfindahl index)	-0,3578 (0,8888)		
Concentration ratio	-0,3578 (0,9906)		
Profitability and competition	0,0496 (0,3890)		
Dummy for Other urban regions	-0,2768* (0,1556)	-0,3242** (0,1407)	
Dummy for rural regions close to centres	0,1648 (0,1898)	0,0875 (0,1699)	
Dummy for Rural and peripheral regions	-0,3442* (0,1914)	-0,3605** (0,1739)	
Dummy for Other urban regions and Rural and peripheral regions			-0,3609*** (0,1154)
Log likelihood	1289,46	1941,338	1941,643
Number of observations	1278	1562	1562

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

### *Predictions of firms R&D probability*

This section discusses and analyses the influence of the determinants on firms' decisions to perform R&D. Assuming the logistic probability function, equation (1) and (2), the estimates in Model 3, Table 3, are used to calculate the R&D probability for firms with different characteristics and locations.

Apart from age and employment size of firms the regressors in the model are dummy variables. In the following when either firm's age or size does not enter into the analysis they are set equal to their average, i.e. 25.4 years and nearly 209 employees respectively. When age of the firm enters into the analysis age is presumed to lie in the interval [1, 200] while the employment size of the firm is presumed to lie in the interval [1,5000]. Because there are no correlations between any variables the choice of which variable to illustrate is free. Figure 2 to 6 shows the results of a number of model calculations.

*Figure 2: The expected R&D probability of a 25-year-old manufacturing firm belonging to a group of firms*

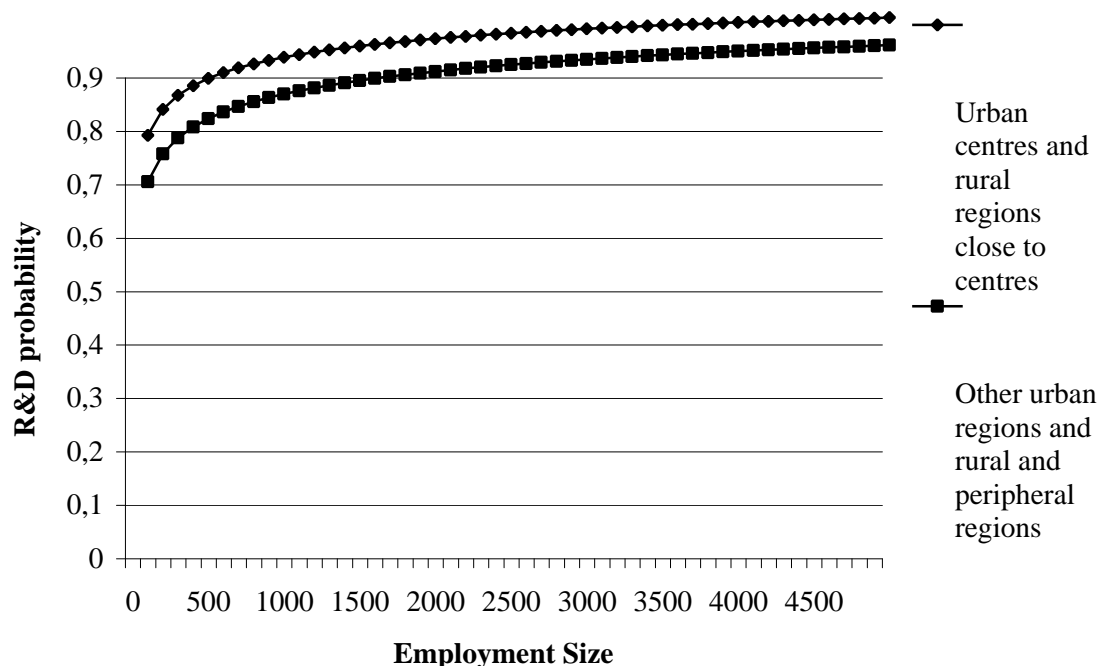


Figure 2 shows that the R&D probability that a manufacturing firm belonging to a group of firms is engaged in R&D increases degressively with firms' employment size. In conformity with the urban hierarchy hypothesis firms located in the urbanization area accounting for 'urban centres and rural regions close to centres' are more likely to be

engaged in R&D than firms located elsewhere. The distance between the R&D probability curves of the two urban regions is significant with a difference of approximately 6-percentage points.

**Figure 3: The expected R&D probability of a manufacturing firm belonging to a group of firms with an employment staff of nearly 209**

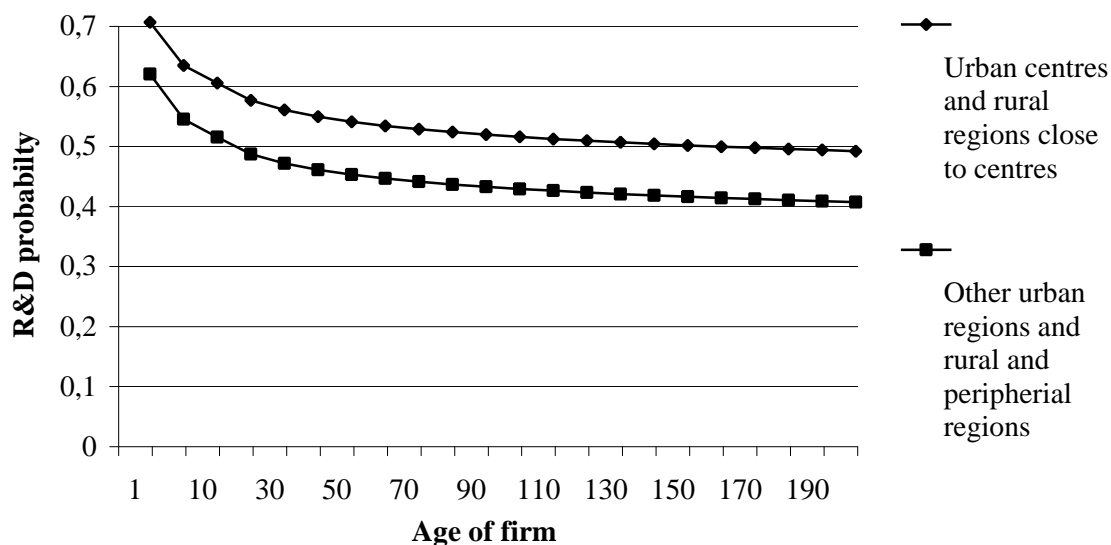
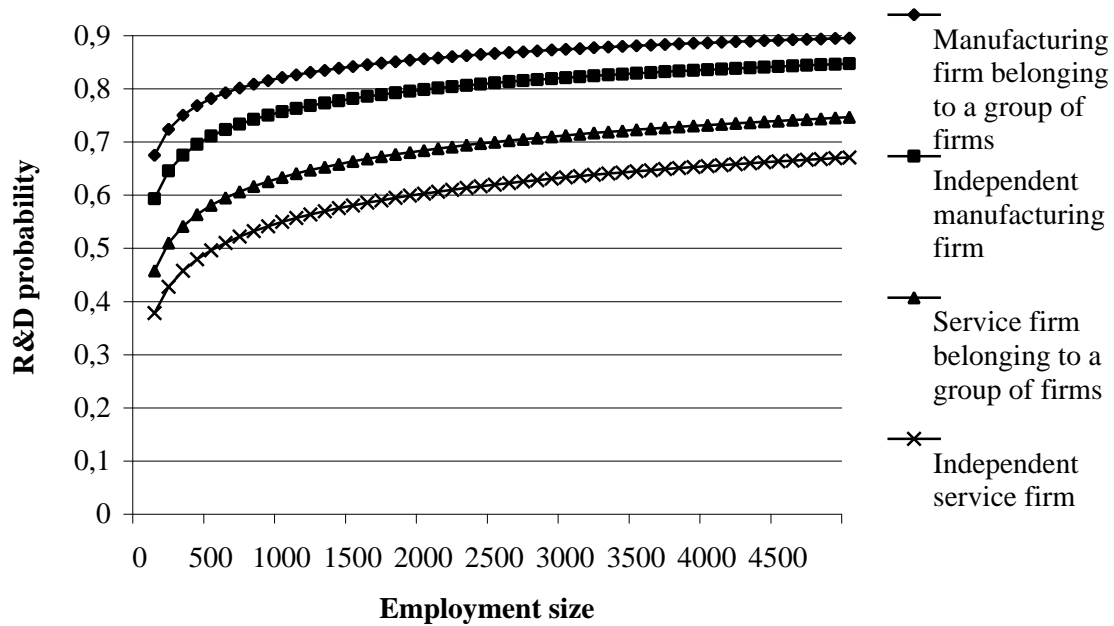


Figure 3 shows that the R&D probability that a manufacturing firm belonging to a group of firms is engaged in R&D decreases degressively with age of the firm, meaning that younger firms are more likely to be involved in R&D than older. As in Figure 2, firms located in the merged region accounting for ‘urban centres and rural regions close to centres’ are more likely to be involved in R&D than firms elsewhere. The distance between the two urbanization areas is significant with a difference of approximately 9-percentage points.

Figure 4 illustrates R&D probability curves for different types of firms located in the urbanization area accounting for ‘urban centres and rural regions close to centres’.



*Figure 4: The expected R&D probability of a 25-year-old firm as a function of employment size, business sector and ownership*



The levels of the R&D probability curves indicate that manufacturing firms are more likely to be engaged in R&D than service firm and that firms belonging to a group of firms within both business sectors are more likely than independent firms. The difference between manufacturing and service firms is approximately 18-percentage points, while the difference between ownership is approximately 7-percentage points.

Hence, the regional location of the firm is of less importance for firms' decisions to perform R&D compared to both ownership and business sector. The business sector of the firm is apparently of greatest significance.

#### **4.2 Regional location and the R&D intensity**

This section focuses on the influence of firms' location and other non-regional determinants on the R&D intensity. Referring to the definition in the introduction the R&D intensity is mainly calculated as the sum of R&D man years as a percentage of all employees in firms which perform R&D activities. The Tobit model has been used to analyse the R&D intensity,  $y^*$ , which is a censored variable. Based on the assumption of normality the distribution of the sample data is a mixture of discrete and continuous distributions.

To analyse this distribution, a new random variable  $y$  is defined

$$\begin{aligned} y &= 0 && \text{if } y^* \leq 0 \\ y &= y^* && \text{if } y^* > 0 \end{aligned}$$

where  $y_i^* = \mathbf{b}_0 + \sum \mathbf{b}_j x_{ij} + u_i$  is the regression model.

Table 4 presents the estimation results of the Tobit model. R&D intensity is affected positively if the firm is a manufacturing firm and if it belongs to a group of firms. The age of the firm has a depressive influence on the R&D intensity, e.g. the R&D intensity is greatest for very young firms. In Model 2 and 3, Table 4, the parameter estimate of ‘age squared’ is not significant owing to multicollinearity<sup>3</sup>. In accordance with expectations the R&D intensity is further affected significantly by the concentration ratio; firms that perform R&D are less R&D intensive if they operate in markets where the market concentration ratio is either very low or high.

To estimate whether the urban hierarchy hypothesis is of any significance for the R&D intensity the dummy variables for regional location have been analysed. Results are identical with the analysis of the R&D probability: the urban hierarchy hypothesis is strongly supported when regions are divided into two urbanization areas; one accounting for firms located in the ‘urban centres and rural regions close to centres’ and the other accounting for firms located in ‘other urban regions and rural and peripheral regions’. Firms located in ‘urban centres and rural regions close to centres’ are more intensively engaged in their R&D than firms located elsewhere.

**Table 4: Tobit models of firms' R&D-intensity, 1997**

Determinants	Model 1	Model 2	Model 3
Intercept	0,1120 (0,0746)	0.0795 (0.0711)	0,0734 (0,0712)
Log of employment size	0,0030 (0,0053)		
Dummy for independent firm	-0,0390*** (0,0151)	-0.0668*** (0.0149)	-0,0695*** (0,0149)
Dummy for manufacturing firm	0,0496*** (0,0152)	0.0561*** (0.0161)	0,0498*** (0,0155)
Age (Log of firm's age)	-0,1279*** (0,0475)	-0.1003** (0.0455)	-0,0985** (0,0455)
Age squared	0,0180** (0,0079)	0.0114 (0.0074)	0,0111 (0,0074)
Solvency Ratio	-0,0049 (0,0092)		
Concentration ratio (Herfindahl index)	0,2695*** (0,0940)	0.3430*** (0.1002)	0,3374*** (0,1004)
Concentration ratio	-0,2501** (0,1024)	-0.3255*** (0.1119)	-0,3178*** (0,1120)
Profitability and competition	-0,0409 (0,0408)		
Dummy for Other urban regions	-0,0486** (0,0170)	-0.0664*** (0.0184)	
Dummy for rural regions close to centres	-0,0238 (0,0201)	-0.0353 (0.0218)	
Dummy for Rural and peripheral regions	-0,03667* (0,0208)	-0.0515** (0.0228)	
Dummy for Other urban regions and Rural and peripheral regions			-0,0517*** (0,0151)
Log likelihood	568,336	946,379	951,409
Number of observations	1285	1588	1588

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

## 5 Conclusion

The aim of this paper is to analyse the importance of firms' location to their R&D behaviour. The basis of the analysis is the urban hierarchy hypothesis that assumes that a firm's R&D behaviour depends negatively on the distance between the location of the firm and an urban centre. Danish municipalities have therefore been classified into four urbanization areas that account for the population size of the municipality and its distance to an urban centre.

Since the four urbanization areas do not differ significantly from each other they have been reduced into two: one area accounting for firms located in 'urban centres and rural regions close to centres' and another accounting for firms located in 'other urban centres and rural and peripheral regions'. The R&D behaviour between firms located in the final two urbanization regions is significantly different as firms located in 'urban centres and rural regions close to centres' are both more likely to be engaged in R&D and engage themselves more intensively in R&D. This result is contrary to Kleinknecht and Poot's (1992) results on Dutch data, as they found no evidence supporting the urban hierarchy hypothesis. The conclusion does not however cast any light on whether the difference is due to the stage of lifecycle that the innovation is in.

Both firms' decisions to perform R&D and their R&D intensity is affected positively if the firm is a manufacturing firm, if it belongs to a group of firms and if it is younger. The employment size of the firm only has a significant effect on a firm's decision to perform R&D; the larger the firm's employment size the more likely it is to be engaged in R&D. While the employment size of the firm has no effect on a firm's R&D intensity, the market concentration ratio has a significant effect; firms operating in markets with either a very low or high market concentration ratio engage themselves less in R&D than firms operating in markets in between. Non-regional determinants such as profitability and solvency ratio could not be proven to have any significant effect on firms' R&D behaviour. Finally, in the case of firms' decisions to perform R&D the affect of business sector is greater than that of ownership while firms' regional location seems to be of less importance.

## Notes

1. This argument is in opposition to the liquidity constraint hypothesis that uses profitability as an indicator for liquidity. In that case, a positive relationship between R&D investments and the profitability of the firm is normally expected, see solvency ratio.

2. The concentration ratio of the Herfindahl-type is for each business sector given by:

$$H = \sum_i \left( \frac{\text{turnover of firm } i}{\text{total turnover of the business sector}} \right)^2$$

3. If model 2 and 3 are estimated on the sample of model 1, table 4, the log-likelihood is estimated to 580.017 and the estimates of variables 'age' and 'age squared' become significant. Both variables have therefore been kept in the model.

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