

DETERMINANTS OF INTERNAL AND EXTERNAL R&D:  
SOME DUTCH EVIDENCE\*\*\*

BY

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1 INTRODUCTION

Innovating firms have to decide whether to start off R&D projects either internally or externally. By internal R&D we mean a firm's in-house R&D, while external R&D refers to R&D that is contracted out to external research organisations such as universities. External R&D can be used by firms to overcome the limitations of their R&D budgets<sup>1</sup> and the technological risks associated with R&D. Firms can benefit from the scale economies of external research organisations that can achieve a large scale in terms of researchers working on a particular problem and in providing research equipment. On the other hand, complementarities between internal R&D and other activities of a firm can be used to improve productivity. Moreover, firms may have insufficient control over results of external research. Using internal R&D, firms may face less danger of an outflow of important information to rival firms which prevents the innovating firm from reaping the rewards or even from recovering the costs of R&D.<sup>2</sup> It may also be attractive for firms to engage in internal R&D parallel with external R&D. Mowery (1983) argues that external R&D functions are a complement to rather than a substitute for internal R&D, while Link and Rees (1991) suggest that firms can use their university-based associations to leverage their internal R&D.

The weight that is given to the pros and cons of internal and external R&D

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1 The limitations of R&D budgets may for instance arise from the indivisibility of expensive, specialized research equipment.

2 See also Dosi (1988) for a discussion of disadvantages of external R&D.

may depend on the firms' market structure characteristics. Limitations of R&D budgets are more important for small firms than for large firms, while firms operating in concentrated markets will put more weight upon preventing rival firms from getting information on research results. That is, the occurrence of internal and external R&D may be explained by different market structure characteristics and, furthermore, market structure characteristics may explain the share of internal or external R&D in total R&D. A generally accepted set of market structure characteristics has been developed in the literature in order to explain inter-firm levels of R&D activity,<sup>3</sup> but we do not know of any systematic, empirical analysis of the impact of market environment on internal *vs* external R&D.<sup>4</sup> In the current study we shall empirically examine the determinants of the two types of R&D by separately regressing internal and external R&D measures for firms in Dutch manufacturing on firm size, market concentration, capital intensity, profitability, market growth, and (skilled) labour intensity. To examine the relative importance of external R&D, the share of external R&D in total R&D is regressed on market structure characteristics.

The structure of this study is as follows. Section 2 discusses the R&D data. The arguments for considering the market structure characteristics used as determinants of internal and/or external R&D are given in section 3. Cross-section regression results are presented in section 4. Some concluding remarks are made in section 5. The results indicate differences in determinants between internal and external R&D. While internal R&D is significantly explained by market concentration, market growth, and labour intensity, external R&D is significantly related to firm size and market growth. Firm size, market concentration, and capital intensity significantly explain the share of external R&D.

## 2 R&D DATA

R&D intensity is defined as the number of full-time employees (FTEs) engaged in R&D as a percentage of total employment.<sup>5</sup> The data are from the '1984 Stichting voor Economisch Onderzoek der Universiteit van Amsterdam (SEO) national survey on R&D and innovation in The Netherlands.'<sup>7</sup> The data consist of internal and external R&D employment and total employment for 446 firms in Dutch manufacturing classified according to three digit 'Standaard Bedrijfsindeling' (SBI) (standard business classification) codes. Using the data for these 446 firms engaged in both internal and external R&D the two digit SBI industries' averages of firm size and internal and external R&D intensities have

3 See Cohen and Levin (1989) and Kamien and Schwartz (1982).

4 Recently, Kleinknecht and Reijnen (1991) and Link and Rees (1991) have studied the influence of market structure characteristics on R&D cooperation, but they did not compare their outcomes with results for internal research.

5 See Cohen and Levin (1989) for a discussion of the different measures of innovation and their pros and cons.

been computed. Table 1 reports the averages for the industries for which at least 10 observations are available. Firms engaged in both internal and external R&D are usually larger firms. This is confirmed by the industries' averages of firm size reported in Table 1. The mean internal and external R&D intensities indicate that firms prefer internal to external R&D. It is not surprising that the paper industry and the building materials industry are found to have the lowest total R&D intensities (1.68 and 2.37, respectively) and that the electrical engineering industry and the chemical industry are found to have the highest total R&D intensities (6.55 and 7.15, respectively).

### 3 DETERMINANTS OF INTERNAL AND EXTERNAL R&D

There have been numerous empirical studies of inter-firm differences in R&D spending. Although many candidate determinants of R&D have been considered, six are commonly analyzed: firm size, market concentration, capital intensity, profitability, market growth, and skilled labour. In the current study we measure firm size by the number of FTEs, market concentration by the four-firm concentration ratio in terms of employment, capital intensity as the ratio of the cumulative investments in the preceding seven years to the industrial production value, profitability by the price-cost margin defined as the

TABLE 1 – MEAN FIRM SIZE AND INTERNAL AND EXTERNAL R&D INTENSITIES BY TWO DIGIT INDUSTRIES<sup>a</sup>

industry	firm size <sup>b</sup>	internal R&D intensity <sup>c</sup>	external R&D intensity <sup>c</sup>
Food	558.5 (1024.2)	1.842 (1.605)	0.591 (0.871)
Textiles	421.4 (578.8)	2.547 (2.137)	1.102 (1.327)
Lumber	308.4 (712.1)	2.346 (2.416)	0.345 (0.220)
Paper	229.5 (158.1)	1.226 (0.799)	0.451 (0.413)
Printing	303.2 (445.2)	1.683 (1.290)	1.005 (1.006)
Chemicals	968.2 (4538.1)	5.811 (4.927)	1.334 (1.961)
Rubber and Plastic	600.5 (1662.6)	4.678 (7.641)	0.953 (1.236)
Building Materials	115.9 (112.2)	1.658 (1.334)	0.715 (0.635)
Fabricated Metal Products	178.0 (266.2)	3.484 (3.510)	1.034 (0.995)
Mechanical Engineering	225.0 (400.4)	4.441 (4.529)	1.026 (1.147)
Electrical Engineering	294.6 (403.6)	5.300 (4.470)	1.245 (1.674)
Transportation Equipment	1370.3 (2738.8)	3.022 (2.805)	0.954 (1.070)

<sup>a</sup> The industry means are unweighted averages of three digit SBI industry values. For these averages only firms engaged in both internal and external R&D have been considered. Only the averages based on at least 10 observations are reported. Standard errors are listed in parentheses.

<sup>b</sup> Firm size is defined as the number of full-time employees (FTEs).

<sup>c</sup> Internal (external) R&D intensities are defined as the number of FTEs engaged in internal (external) R&D as a percentage of total employment (in FTEs).

ratio of the industrial production value minus labour and material costs to the industrial production value, market growth as the percentage change in deflated industrial sales, and skilled labour by the ratio of labour costs to the industrial production value.

The firm size is known for each of the 446 firms. For the other explanatory variables, we use three digit SBI data from the DUMA (Dutch Manufacturing) data set of the Research Institute for Small and Medium-Sized Business (EIM) in The Netherlands. For these three digit SBI variables we use the averages of the 1981, 1982, and 1983 values for the three digit SBI industries to which the individual firms belong. It is unrealistic to argue that the 1983 R&D projects only depend on the market structure prevailing in 1983. Decisions on these R&D projects will often have been made in the preceding years so that the market structure characteristics for 1981 and 1982 may also explain the 1983 R&D intensities.

Large firms are more likely to engage in internal than external R&D. This can be justified by the financial arguments which are also suggested to justify the Schumpeter (1950) and Galbraith (1952) hypothesis that a large firm size is a necessary condition for technological innovation.<sup>6</sup> Internal R&D projects may be more expensive than external R&D projects and can therefore more easily be started off by large firms than by small firms.<sup>7</sup> Large firms usually have more financial resources<sup>8</sup> and can spread the fixed costs of internal R&D over a larger sales volume. Large firms can use their substantial resources to finance internal R&D projects in an internal fashion, while small firms need to convince commercial banks of the solidity of their prospective innovative projects.

Beside financial reasons there are also technical reasons for large firms to engage in internal R&D. Large firms can better use the complementarities between internal R&D and their other activities to improve productivity. Moreover, Mowery (1983) suggests that research projects of large firms are often more risky and complex and, therefore, require specific knowledge that cannot be provided for by organisations not engaged in the firms' production processes. The complex research projects of large firms must form the core of the internal R&D projects.

6 A more bureaucratic decision-making process and less motivated scientists and entrepreneurs may negatively affect innovation in large firms. See Baldwin and Scott (1987, pp. 75–88), Cohen and Levin (1989, pp. 1067–1074), and Kamien and Schwartz (1982, pp. 31–33) for a discussion of the relationship between firm size and innovation.

7 External R&D can also be expensive but the indivisibility problem with expensive research equipment may make internal R&D less attractive than external R&D for firms having no substantial financial resources.

8 Hall and Weiss (1967) conclude that larger firms tend to have high profit rates.

Small firms have to overcome the limitations of their R&D budget by using external instead of internal R&D. Kleinknecht and Reijnen (1991) and Link and Rees (1991) argue that it is attractive for small firms to contract R&D out or to cooperate with other firms. Mowery (1983) argues that the primary beneficiaries of services provided for by external research organisations have been small firms, because small firms usually cannot support an in-house laboratory.<sup>9</sup>

The two themes in Schumpeter's discussion predicting a positive effect of market concentration on innovation can also be interpreted as predicting stronger incentives to engage in internal R&D than in external R&D.<sup>10</sup> Firstly, firms should expect some form of *ex post* market power in the market for their invented products and processes. This *ex post* market power allows for non-competitive profits providing a reward for innovation and compensating the costs of R&D.<sup>11</sup> To assure *ex post* market power firms need to prevent an outflow of technological information about their innovations to rival firms. This outflow in conjunction with the large market shares of rival firms in concentrated markets leads to a considerable reduction of the reward for the innovator. Because of the insufficient control over external research results, firms operating in concentrated markets may prefer internal to external R&D. Of course, innovations will eventually be noticed by rival firms, but internal R&D may be the best way to delay imitation until the products are marketed or new processes are in commercial use. Internal R&D may give a firm a valuable lead time over its rivals in a concentrated market.<sup>12</sup>

Secondly, *ex ante* market power should favour innovation. *Ex ante* market power reduces the uncertainty which usually undermines incentives to invest in R&D, and provides firms with additional financial resources. These additional financial resources are beneficial to internal R&D. Market power makes it financially less necessary to engage in external R&D to overcome the limited R&D budgets. Since the additional financial resources provided by *ex ante* market power allow for an internal financing of R&D, these resources might also assure the *ex post* market power. Kamien and Schwartz (1978, p. 252) give two reasons for internal financing: firstly, 'external financing may be difficult to obtain without substantial related tangible collateral to be claimed by the

9 Mowery (1983) and Varcoe (1974) note that it is difficult for small firms to utilize external research facilities. Small firms usually do not have the in-house expertise to articulate their research needs and to put those needs into scientific terms.

10 For extensive discussions of the impact of market power on innovation we refer to Cohen and Levin (1989, pp. 1074–1078) and Kamien and Schwartz (1982, pp. 27–31).

11 The most obvious index measure for the extent of imperfect competition in a market is the degree of concentration. Of course, the concentration ratio can be a weak measure of market power and will in practice contain substantial errors.

12 See Peck (1986) for a discussion of the importance of a lead time in the computer and semiconductor industries.

lender if the projects fails,' and secondly, 'the firm might be reluctant to reveal detailed information about the project that would make it attractive to outside lenders, fearing its disclosure to potential rivals.' The four-firm concentration ratio is used to examine the effects of *ex ante* market power on innovation.

If we consider the discussions in the literature of the impact of capital intensity on innovation, we would predict that capital-intensive industries are not beneficial to external R&D. Comanor (1967) associates entry barriers such as high capital intensity with market power and, from our point of view therefore, with high levels of internal R&D. Mansfield *et al.* (1977) suggest that high capital intensity hampers the entry of new firms which are among the most important contributors to innovation. We expect that new (small) firms in particular will contribute to innovation by using external R&D. Capital intensity can also be seen as an indicator of scale economies. According to Galbraith (1952) and Scherer (1980), scale economies positively influence innovation. They argue that scale economies in certain parts of a firm's operation may provide scope economies for R&D. To exploit these scope economies internal R&D will be chosen instead of external R&D.

Effects of profitability on R&D have been argued for in various studies.<sup>13</sup> Assuming that a firm's financial position is a key factor for the choice between internal and external R&D, we expect a stronger positive effect of profitability on internal than on external R&D. A firm that makes huge profits can internally finance the more expensive in-house R&D projects. Branch (1974, p. 1001) argues that 'borrowing or the issuance of new equity securities is an unlikely source of funds for the support of R&D projects' because of the risks associated with R&D.

A firm's market growth has implications for its research opportunities. Coate and Uri (1988) argue that rapidly growing industries assimilate and promote new innovations, while Acs and Audretsch (1987) note that in the growth stages there is no standardized concept in the market and the product design is subject to rapid change and evolution.<sup>14</sup> Rapidly growing industries are therefore likely to offer rich opportunities for R&D. The implications of market growth for the choice between internal and external R&D are considered by Asch and Seneca (1975) and Palmer (1972). They argue that firms in declining industries are more likely to collude than firms in growing industries. While these authors discuss a different issue, it is clear that some of their arguments also apply to a cooperation with external research organisations on R&D. Both collusion and external R&D can for instance accomplish a larger scale in terms of researchers working on a project and in providing research

13 See for instance Coate and Uri (1988), Grabowski (1968), Link (1982) and Van den Berg (1989).

14 Farrell and Saloner (1985) argue that an industry that is bound together by the benefits of standardization may be less innovative.

TABLE 2 – CORRELATION MATRIX

	Firm Size	Market Concentration	Capital Intensity	Profitability	Market Growth	Labour Costs/Sales
Firm Size	1.00					
Market Concentration	0.14	1.00				
Capital Intensity	-0.05	0.06	1.00			
Profitability	0.01	0.09	0.28	1.00		
Market Growth	0.13	0.20	-0.36	0.02	1.00	
Labour Costs/Sales	-0.10	-0.29	0.38	0.18	-0.41	1.00

equipment. In growing markets firms may be less motivated to exploit the benefits of collusion or external R&D.

Kraft (1989) and Acs and Audretsch (1988) suggest that the skill structure of employees is a determinant of innovation. Firms with better trained employees may have more opportunities to engage in R&D, and especially in internal R&D. They do not need external experts to solve their problems. We assume that a higher ratio of labour costs to production value reflects the higher salaries for well trained employees. Of course the ratio is only a crude proxy for skilled labour.<sup>15</sup>

#### 4 RESULTS

To examine whether the explanatory variables are strongly correlated and thereby cause problems of multicollinearity, the correlation matrix is presented in Table 2. Most of the correlation coefficients indicate that there are no problems of multicollinearity. For the variables that are strongly correlated with other variables, we have estimated models with a smaller set of variables to see whether the coefficient estimates are affected by the correlation. The estimation results were not significantly affected.

The linear cross-section regression results for 446 firms in Dutch manufacturing are shown in Table 3.<sup>16</sup> The results are shown for analogous regressions where total R&D intensity, internal R&D intensity, external R&D intensity, and the share of external R&D in total R&D are the dependent variables. Since the errors of the internal and external R&D regressions are presumably interre-

15 Since the ratio of labour costs to production value can also be seen as a measure of labour intensity, correlation with capital intensity and problems with multicollinearity may be expected. However, the correlation is only 0.38 and the coefficient estimates of the other variables are only slightly affected by the presence of this ratio in our model.

16 Using logarithmic regression equations, the coefficient estimates are only slightly different from the coefficient estimates of the linear model.

TABLE 3 – LINEAR REGRESSIONS OF INTERNAL AND EXTERNAL R&D INTENSITIES (STANDARD ERRORS IN PARENTHESES)<sup>a</sup>

Equation/ variable to be explained	Firm Size	Market Concen- tration	Capital Intensity	Profi- tability	Market Growth	Labour Costs/ Sales	Constant	Sample Size	R <sup>2</sup>
1/ Total R&D intensity	-0.626 (1.102)	4.410 <sup>b</sup> (1.012)	-1.622 (1.733)	0.642 (4.035)	19.619 <sup>b</sup> (4.747)	9.365 <sup>b</sup> (2.760)	0.675 (1.009)	446	0.091
2/ Internal R&D intensity	-0.009 (0.947)	4.112 <sup>b</sup> (0.920)	-1.543 (1.542)	0.014 (3.591)	15.822 <sup>b</sup> (4.224)	8.167 <sup>b</sup> (2.456)	0.246 (0.897)	446	0.075
3/ External R&D intensity	-0.620 <sup>b</sup> (0.291)	0.350 (0.283)	-0.078 (0.472)	0.628 (1.100)	3.767 <sup>b</sup> (1.294)	1.198 (0.752)	0.429 (0.275)	446	0.022
4/ External R&D Share	-0.112 <sup>b</sup> (0.042)	-0.097 <sup>b</sup> (0.041)	0.151 <sup>b</sup> (0.068)	0.003 (0.159)	0.039 (0.187)	-0.123 (0.109)	0.264 <sup>b</sup> (0.040)	446	0.040

<sup>a</sup>The method of Seemingly Unrelated Regressions has been used to estimate equations 2 and 3.

<sup>b</sup>Statistically significant at the 95% level of confidence.

lated, the method of seemingly unrelated regressions has been used to estimate the coefficients of these two regressions.<sup>17</sup> The low standard  $R^2$  is explained by the higher aggregation level of the market structure variables. Except for firm size, three digit industry market structure variables are used to explain R&D intensities of firms such that most of the explanatory variables have the same values for several R&D observations.

In most R&D studies the decomposition of total R&D into internal and external R&D is not accounted for. That is, most authors assume that the determinants of internal and external R&D are the same. Our results indicate that this assumption can be criticized. For capital intensity and the price-cost margin the decomposition does not seem to be relevant; they affect neither the total, nor the internal or external R&D intensities. But the other market structure characteristics considered have different effects on internal and external R&D. Equation 1 shows that a modelling of the total R&D intensity leads to the conclusion that firm size does not affect R&D (coefficient  $-0.63$  with

17\_ The test for heteroscedasticity proposed by White (1980) indicated that homoscedasticity could not be rejected.

$t$ -value  $-0.57$ ) and that market concentration and the ratio of labour costs to sales do affect R&D (the coefficients are 4.41 and 9.37 with  $t$ -values 4.36 and 3.39, respectively). However, a separate modelling of the internal and external R&D intensities indicates that firm size only significantly affects the external R&D intensity (coefficient  $-0.62$  with  $t$ -value  $-2.13$ ) and that market concentration and the labour-sales ratio only significantly affect the internal R&D intensity (the coefficients are 4.11 and 8.17 with  $t$ -values 4.47 and 3.33, respectively). Differences in effects are also indicated by the results of Table 4. Table 4 gives the results of tests examining whether individual variables have identical effects on internal and external R&D.  $F$ -tests reject the hypothesis of identical effects for market concentration, market growth, and the labour-sales ratio.

The negative coefficients of firm size suggest that the advantages of a large firm size (increasing returns to scale, scope economies) are compensated or even dominated by the disadvantages (loss of managerial control and bureaucratization of inventive activity). The positive market concentration coefficients are pointed out by Schumpeter (1950). In growing markets R&D efforts seem to be higher indeed, while our proxy for skilled labour also has the expected positive effect on R&D.

A separate modelling of internal and external R&D cannot provide meaningful insights into the determinants of the relative importance of the two forms of R&D for firms, because the resulting differences in coefficients only provide information on the impact of market structure characteristics on the absolute differences in importance between internal and external R&D. It is more interesting to examine the relative differences by modelling the share of external R&D in total R&D.

Equation 4 of Table 3 shows that the coefficients of the external R&D share regression indicate that firm size, market concentration, and capital intensity significantly explain the relative importance of external R&D for firms. As expected, large firms in concentrated markets seem to prefer internal R&D to external R&D. The finding that capital-intensive industries favour external R&D is not in line with the impact of capital intensity on innovation suggested

TABLE 4 – HYPOTHESES TESTS FOR THE DIFFERENCES IN THE DETERMINANTS OF INTERNAL AND EXTERNAL R&D (BASED ON EQUATIONS 2 AND 3 OF TABLE 3)

Variable <sup>a</sup>	Firm Size	Market Concentration	Capital Intensity	Profitability	Market Growth	Labour Costs/Sales
$F$	0.445	17.743 <sup>b</sup>	0.977	0.032	8.768 <sup>b</sup>	8.708 <sup>b</sup>

<sup>a</sup> The variable is hypothesized and therefore constrained to have an identical effect on internal and external R&D.

<sup>b</sup> Statistically significant at the 95% level of confidence.

in the literature. However, the positive capital intensity coefficient might be explained by the fact that capital-intensive high-tech industries often need external experts to solve their problems.

## 5 CONCLUDING REMARKS

Most empirical studies of the determinants of R&D have treated R&D as a single homogeneous activity. Consequently, little empirical information on the determinants of internal and external R&D is available. In the current study, we show that market structure characteristics influence internal and external R&D in a different manner.

Many discussions on the effects of market structure characteristics on innovation are based on financial arguments. This especially applies to firm size and market concentration. In Schumpeter's discussion on the importance of firm size and market power for innovation, the opportunities to make higher profits are the central theme. In this study the importance of these financial arguments is confirmed by considering the choice between internal and external R&D. Since this choice depends on the financial position of a firm, negative effects of firm size and market power on the share of external R&D in total R&D are expected.

Governments often offer firms the (subsidized) services of external research organisations to ensure that all firms can have the advantage of ongoing technological developments. Especially small firms are expected to benefit from such research services. Our results indicate that smaller firms are indeed more likely to engage in external research relationships. But our results provide a more detailed description of the firms that are interested in such services. Especially firms dealing with more competition and capital-intensive production processes will consult external experts.

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### Summary

#### DETERMINANTS OF INTERNAL AND EXTERNAL R&D: SOME DUTCH EVIDENCE

Innovating firms can choose to engage in either internal or external R&D, or in both. In the current study, we shall examine internal and external R&D separately to determine empirically the market structure characteristics explaining the external R&D share and the differences in market structure determinants between internal and external R&D. Our results indicate that a government policy that aims at stimulating technological progress by offering external research facilities is particularly interesting for smaller, capital-intensive firms operating in less concentrated markets.