Determinants of Research and Development Expenditures in the Forest Products Industry¹

by

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Abstract

Research and development (R&D) activities have long been recognized as an important component of industrial activity. In fact, for many industries such as pharmaceuticals and electronics, successful R&D programs are a necessary condition for firm survival and growth. This study examines the R&D decisions of forest products firms by assessing the relationship between R&D, profitability, and growth; identifying differences in R&D efforts and the determinants of R&D among pulp and paper and solidwood industries; and evaluating the desirability of employing simultaneous equations to model firm-level decision making. Information was collected for the years 1974 to 1993 on R&D expenditures, employment, assets, sales, and income and evaluated using a three-stage least squares model. The results, that R&D, profitability, and growth of forest products firms are related, are similar to those of previous research on other industries. Size and profitability were positively related to R&D expenditures, and R&D and growth were positively related to profitability. Finally, R&D expenditures were negatively related to growth while profitability was positively related. The analysis did not reveal any significant differences in R&D relationships between the solidwood and pulp and paper industries.

INTRODUCTION

Research and development (R&D) activities have long been recognized as important components of industrial activity. For industries such as pharmaceuticals and electronics, successful R&D programs are a necessary condition for firm survival and growth. As a consequence, economists have been evaluating the relative importance of factors that may affect R&D expenditure decisions.

As Kamien and Schwartz (1975) note, most analysts historically have viewed research and technical advance as separate from a firm’s goals of profitability and growth. Much of the research on industrial R&D activities has focused on exploring the relationship of R&D effort and firm size. Kamien and Schwartz (1975) provide an excellent review of research conducted prior to 1975, noting that there is little evidence to support the hypothesis that “innovative effort increases with firm size.”

Examining the relationship between firm size and the R&D effort of individual industries provides markedly different results, however. Mansfield (1968) assessed the R&D effort-size relationship for several types of industries, and reported that, at least for the chemical industry, size was significantly related to R&D effort. Loeb and Lin (1977) applied several single equation models to assess the relationship between size and R&D in the pharmaceutical industry. Using time series data, they noted a significant positive relationship.

In addition to the single equation studies, researchers have begun to explore the relationship between R&D and firm size through the use of simultaneous equations. Moreover, economists have also begun to examine the relationships between R&D, growth, and profitability. While some scientists have utilized single equation models to investigate these relationships (Mansfield 1968; NSF 1973; Griliches 1973; Loeb and Lin 1977), simultaneous equations may provide a more realistic representation of the R&D decision. Specifically, the literature reveals that while R&D is related to size and profitability, profitability is impacted by R&D and growth. Similarly, growth of firms has been linked to R&D and profitability. Simultaneous equations are capable of modeling these endogenous relationships (Loeb 1984, 1983; Mansfield 1968; Mueller 1967).

Mueller (1967) conducted one of the initial investigations of the firm decision process using simultaneous equations. Mueller developed equations to assess firm decisions regarding capital investment, research and development, advertising, and dividends. Loeb (1983, 1984) built on this model to assess the simultaneous interaction among R&D, profitability,

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and growth. The results revealed that the three components are indeed linked. As hypothesized, profitability was a significant variable in the R&D equations and positively related to R&D. In the profitability equations, both R&D and growth exhibited a significant and positive effect. Interestingly, R&D was reported to be negatively related to growth. Loeb hypothesized that current R&D expenditures may compete with investments in assets for the firm's resources during the current period.

Forestry examples are rare. Bullard and Straka (1986) utilized a single equation model to examine company sales and dollars spent on R&D by five major U.S. pulp and paper firms from 1975 to 1984. Their analysis revealed a significant positive relationship between the two variables. Hyde et al. (1992) conducted a comprehensive study of returns to public investment in forestry research in a number of industrial sectors within the broad umbrella of the forest products industry. They noted that returns to investment were greatest at the manufacturing level.

The primary purpose of this paper is to examine private R&D expenditures in forest products industries, particularly the solidwood and the pulp and paper industries. Specific topics addressed include assessing the extent of the relationship between R&D, profitability, and growth in the forest products industries; identifying differences in R&D efforts and the determinants of R&D among the pulp and paper and solidwood industries; and evaluating the desirability of using simultaneous equations to model firm-level decision making. The following sections describe the data and methodology used in this study, give an overview of the study results, and discuss the key findings and implications for future research.

**DATA**
The data consisted of information collected from 303 firms over a wide range of industries. We obtained data for firms classified in Standard Industrial Classification Codes (SIC) 24 (Lumber and Wood Products) and 26 (Paper and Allied Products). Information was collected for the years 1974 to 1993 on R&D expenditures, employment, assets, sales, and income. The data were obtained from the COMPUSAT database (Standard and Poor's Compustat Services 1988).

**METHODS**
The Simultaneous Equation Model - This study evaluates a simultaneous equation model of firm-level decisions in the forest products industries. Loeb's original model was modified to test for differences between the solidwood and pulp and paper industries. The set of equations used were:

1) \[ R&D_t = f(S_t, \Pi_t, K/L_t) \]
2) \[ \Pi_t = g(R&D_t, G_t, K/L_t) \]
3) \[ G_t = h(R&D_t, \Pi_t, \Pi_{t-1}, \Pi_{t-2}) \]

where:

- \[ R&D_t = \text{R&D expenditures} \]
- \[ S_t = \text{Size} \]
- \[ \Pi_t = \text{Profitability} \]
- \[ K/L_t = \text{Capital/Labor ratio} \]
- \[ G_t = \text{Growth} \]

The variables of interest were calculated as described below:

4) Size = Employees, Total Assets, or Sales

5) Growth =

\[
(\text{Employees}_t - \text{Employees}_{t-1}) / \text{Employees}_t; \\
(\text{Total Assets}_t - \text{Total Assets}_{t-1}) / \text{Total Assets}_t; \\
\text{or} (\text{Sales}_t - \text{Sales}_{t-1}) / \text{Sales}_t,
\]

6) Profitability = Net Income/Stockholders' Equity,

7) Capital/Labor ratio = Stockholders' Equity/Employment.

The R&D variable represents all costs incurred in developing new products or series. It is limited to the company's contribution, and does not include customer or government funding for research and development.

**The R&D Equation (Equation 1)** - As discussed earlier, the relationship of size to R&D intensity has been evaluated extensively. While many of the aggregate studies have revealed little correlation between the two variables, research on specific industries supports the hypotheses that larger firms invest in proportionally more R&D. As Mueller (1976) notes, larger firms are expected to undertake more R&D because they "can command more resources and are... in a better position to assume the uncertainties which accompany this activity."
Three different measures of size were evaluated as listed in equation 4. All three have been offered as appropriate estimates of firm size and have been evaluated in similar R&D studies (Kamien and Schwartz 1982; Loeb 1984). Moreover, as Loeb (1984) notes, there is little information on the potential effects of different measures of size and R&D effort. Thus, our study provides an opportunity to evaluate the differences in the three estimates of size.

The impact of profitability on R&D was also evaluated. Different levels of R&D expenditures may be attributed to the financial position of the firm. Profitability provides one measure of the relative financial position of firms. Conversely, some analysts contend that the link between R&D expenditures and profitability could be exactly the reverse. That is, declines in profitability may prompt a firm to invest more heavily in R&D in hopes of developing new goods to reverse the trend (Loeb 1977). Finally, a capital/labor ratio was included in the R&D equation to account for differences in the capital intensity of firms, particularly as they relate to differences between the solidwood and pulp and paper industries.

The Profitability Equation (Equation 2) - The profitability equation includes measures of R&D, Growth, and Capital/Labor. R&D expenditures were hypothesized to positively affect profitability by increasing sales through the development of new products and series. Additionally, R&D expenditures may result in new processing technology that could increase efficiency. As in the Loeb model, a variable for firm growth was included to assess the possibility that faster growing firms exhibit greater profitability than do slower growing firms. Three separate measures of growth were evaluated: growth in employees, assets, or sales. The growth variable in each set of equations was selected to parallel the size variable. The simultaneous equation model was estimated with the three sets of size and growth variables. If size was defined as number of employees, the growth variable reflected the growth in employees for the firm.

The Growth Equation (Equation 3) - The growth equation included R&D expenditures, and three variables for profitability. R&D was included to reflect the possibility that new technology (new products or processing) developed by research could result in firm growth. Loeb (1983) argues that current or past profitability may provide additional funds for activities that could lead to current growth. Consequently, a measure of profitability in the current year and two lagged profitability variables was included in the equation.

RESULTS
The model was estimated using three-stage least squares. As mentioned earlier, three versions of the model based on different size and growth variables were evaluated. The results for the three models were very similar. The sign of the coefficients and the significance of the variables in all three models were identical. Therefore, the results of the model utilizing number of employees as the measure of size and growth will be presented. Table 1 lists the coefficients and t-statistics for the variables in each equation.

| Table 1. Coefficients of the Simultaneous Equation Model¹ |
|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| Eqn | Constant | R&D1 | S1 | Π1 | K/L1 | G1 | Π11 | Π12 |
| R&D1 | -77.7 (-5.18) | - | 4.45 (16.29) | 269.16 (4.25) | -2.03 (-0.42) | - | - | - |
| Π1 | 0.11 (9.14) | 0.0002 (3.98) | - | - | -0.004 (-0.82) | 0.01 (3.18) | - | - |
| G1 | -6.71 (-6.61) | -0.02 (-3.98) | - | 128.49 (2.32) | - | -60.82 (-1.21) | 1.13 (0.27) |

¹ Numbers in parentheses represent t-values.
The results for the R&D equation for forest industries were similar to those reported by Loeb (1977) for all industries. Size (employees) was positively related to R&D and significant at the .01 level. This result mirrors those of other simultaneous equation studies using various measures of size. As mentioned above, our models using total assets or sales as measures of size produced identical results, with little variation in the actual value of the coefficient. Profitability was also positively related to R&D at the .01 significance level. Conversely, the Capital/Labor ratio was negatively related but not significant. Loeb (1983) and Loeb and Lin (1977) reported that Capital/Labor was negatively and non-significantly related to R&D, suggesting that differences in the capital intensity of the firms do not influence the R&D effort. The non-significance of the variable in our model may be attributed to the lack of variation in the values, as we were examining two closely related industries.

The profitability equation provided results that generally conformed to a priori expectations. R&D was significant at the .01 level and positively related to profitability. Similarly, growth (in number of employees) was significantly and positively related. Capital/Labor, as in the R&D equation, was negatively related to profitability but was not significant.

The Growth equation provided results somewhat different than those reported by previous studies. In our model, R&D was found to be negatively related to growth and was significant at the .01 level. All previous studies utilizing simultaneous equation systems had found R&D to be negatively related, but Loeb (1983) reported the variable to be non-significant. Loeb (1984) noted the negative relationship may reflect R&D expenditures being drawn from funds that would otherwise contribute to the growth of the firm. Only one of the three profitability variables, current profitability, was significant in the growth equation and was positively related to growth.

**SUMMARY AND CONCLUSIONS**

This study was designed to assess the relationships between R&D, profitability, and growth in the forest products industries; identify differences in R&D decisions among the solidwood and paper industries; and evaluate a simultaneous equation model for the forest products industries. Data were obtained for firms in the solidwood and pulp and paper industries for the years 1974 to 1993. The results of the study indicate that R&D, profitability, and growth for forest products firms were related in much the same manner as previous research on other industries has revealed. Size and profitability were positively related to R&D expenditures, and R&D and growth were positively related to profitability. Finally, R&D expenditures were negatively related and profitability was positively related to growth.

The analysis did not reveal any substantive differences between the solidwood and pulp and paper industries. Two separate methods were used to test for differences among the two industries. As in previous studies, a Capital/Labor ratio was utilized to assess the impact of capital intensity on firm R&D effort. Because the pulp and paper firms are typically more capital intensive than solidwood firms, the coefficient of the Capital/Labor ratio variable should identify differences in R&D effort by the two industries. The variable was not significant in either the R&D or profitability equations. The second method, substituting a dichotomous variable that identifies each firm as being in the solidwood or pulp and paper industry, also failed to reveal any differences among the two industries.

Loeb (1984) noted that the simultaneous equation model could identify policy options for government or industry. For example, if R&D in forest industries induces firm growth (i.e., increased employment), "a specific policy which fosters R&D in that industry may be worthy of initiation..." at the government level. Our results do not support this contention, because R&D is negatively related to growth. As mentioned previously, this negative relationship may result from competition for funds within a firm during the current year. Examining the effect of prior R&D expenditures on firm growth may reveal a much different relationship. Regardless of the outcome, the desirability of a change in public policy is questionable. Most firms invest in research to enhance profitability and growth and frequently, this means substitution of capital for labor.

Two modifications to be considered in future analyses involve testing for differences in impacts of R&D expenditures between the solidwood and pulp and paper sectors. Although our analysis did not reveal any substantial differences between the two divisions of the forest products industries, further research is needed in this area. One problem with relying on a Capital/Labor ratio is there may be little variation among the data used to estimate the ratio. Moreover, the industry has become more integrated in recent years with many traditional pulp and paper firms acquiring solidwood product mills. Thus, the SIC codes may not reflect the nature of many of the
firms accurately. An initial step would entail examining the mix of products for firms. This may provide a more reasonable means of classifying firms for analysis.

More work is also needed to adequately model the relationship between R&D expenditures and firm growth. Few forest products firms invest in R&D with expectations of affecting growth in the current year. Instead, R&D provides innovations in processing and products that will increase profitability and growth in the future. The negative and significant relationship revealed by our model may be largely attributed to competition for funds rather than research affecting firm growth. Models developed to further the analysis should incorporate lagged variables for R&D in the growth and profitability equations to account for the nature of R&D impacts.

**Literature Cited**


