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Selected Research Paper: **R12**

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Abbreviations

AST	Investment in plant and equipment, used for firm size control variable
PROF	Annual operating income
R&D	Research and development
RDE	Annual research and development expenditures per dollar revenue
SEMP	Annual sales revenues per employee, used for the firm control productivity variable
TECCT	Technological Cycle Time
TECST	Technological Strength

Structure

I. Introduction

Research and development (R&D) of a product or service plays an important role of the economic well-being of a nation, the profitability of an enterprise, the effectiveness of a technology-based governmental agency, and the enormous investments nations make in R&D activities.

It is the importance of the results of R&D that contribute to the success of the company, respectively the economic system of a nation. This importance is a driver to look at the relations between efforts, respectively R&D spending, and the output variables, that contribute to the R&D performance, and in addition to this the company's success, however these variables will be defined.

If causal relations are known and proved with mathematical, respectively statistical tools, then you can concentrate on the input variables to gain the efficiency of R&D, as a necessary precondition for a company's success.

II. Discussed Concepts in the Research Paper

In the selected research paper R12 from C.Carls Pegels and M. V. Thirumurthy is examined a prove of the effects and causal relationship between R&D investment (measured in terms of R&D expenditure) and firm performance (expressed with annual operating income of the company). These R&D efforts have then the potential to provide competitive advantage resulting in improved firm performance. R&D is to implement in the business strategy, because R&D is a necessary precondition for internal technology development, respectively technology transfer for a base of the own technological strength.

In this article R&D strategy is defined as the R&D efforts. This article emphases two important measures of the technological competitiveness of firms: the technological strength (TECST), based on the number and the current impact index of the firm's products, and the technological cycle time (TECCT). It will be shown that these variables have a strong impact on the firm's success variable annual operating income (PROF).

The authors introduce furthermore two proxy variables for the control of the firm's size measured by investment in plant and equipment (AST), and firm productivity, measured by the annual sales revenues per employee(SEMP) for the firm productivity control variable.

The results of the article are empirical proved by a sample of 49 larger companies from 13 industry groups. The results from this survey served as an input for the multiple regression model, which is declared in the next section. The variables from TECST and TECCT were obtained from the Business Week [4], and their source Chi Research Inc. The financial data needed for this study was gathered from the Compustat files. This annual report in the business week brings a scoreboard in which are 897 companies from 40 industry groups and subgroups examined. As a matter of fact this survey in the Business Week was the motif for he article of the authors, to give evidence that simple correlation applied by the business week is not sufficient.

The authors are going to criticize the application of the simple correlation model at the data in the business week: "*The weakness of the Business Week study lies in the fact that statistically simple correlation coefficients can be relatively weak indicators of a relationship between two variables*."[5] This might be true, but the article in the Business Week is not going to overemphasize the founded high correlation about R&D spending per employee and sales per employee. Furthermore the Business Week states: "*Statistics can never establish causality,..*"[4] As a matter of fact the authors in the selected research paper overemphasizes their findings by interpreting survey data with their own statistical model, expressed through three equations, that show the interdependencies of the above mentioned eight variables. The problem is the relative small sample size of the study of the authors. This will be discussed in section V.

III. Methodology used in the Research Paper

The methodology in the paper is the usage of statistics, respectively mathematical methods to evidence a correlation between dependent and independent variables to declare that simple correlation is not sufficient for relation between R&D spending and company's success and to state that it is the increased knowledge which contributes to the success of a company. The authors apply first the simple correlation on their model to prove a relationship among the 28 pairs of the eight variables.

The model they build is expressed with the following equations:

1) $PROF = f(AST, SEMP, TECCT)$,
2) $TECCT = f(TECST, RDE)$,
3) $TECST = f(RDE, AST)$.

The complete model is shown in Figure 1. It is not the objective of this paper to rewrite the work, which is done in [5], but the drawing is necessary to get a grip from the network of dependencies.

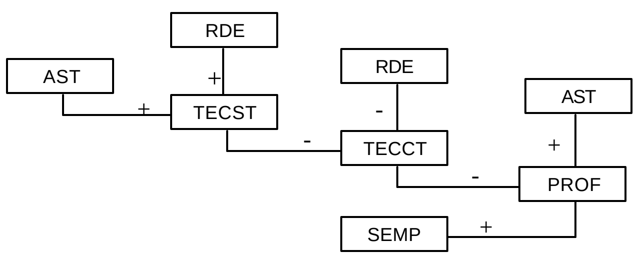

Figure 1: Individual Equations Framework [5]

The hypotheses of the authors are: RDE will have a positive impact on PROF, TECCT will have a negative impact on PROF, because the lower the TECCT the more effective is the firm in managing its R&D, and TECST will have a positive impact on PROF.

To go a little bit deeper for understanding the reasons, why the authors are not satisfied with the simple correlation of the study in the Business Week, it is necessary to explain the used methodology.

Correlation analysis used in the research paper is a statistic tool, that describes the degree to which one variable is linearly linked to another. The Analysis used in conjunction with regression analysis measures how well the regression line explain the variation of the dependent variable. In addition to this correlation analysis measures show the degree of association between two (or more) variables. [27]

The mathematical model for the simple regression for one predictor is:

$y_i = b_0 + b_1 x_i + e_i$, with $i = 1,2,\ldots,n$.[1]

b Regression coefficient, e error

The second methodology applied from the above mentioned three equations is the multiple regression analysis. Multiple regression (one dependent variable) is similar to the simple regression model, but we use a matrix with the scores of the subjects on the predictors.

$$Y = XB + E \quad [1]$$

This regression model is applied on each equation. Besides this a three stage least squares approach is done with each equation.

Why do the authors using the regression model and the equations? The equations are expressing the dependencies between the variables. This model shows that R&D expenditures are not directly linked to the business firm's success, but linked to technological strength (TECST). In the next stage technological strength has an impact on technological cycle time (TECCT). Technological cycle time influences then the annual expected income (PROF) interpreted as the firm's success variable; not mentioned here the influences of SEMP, RDE, and AST. It is a two step model, that is different from the assumptions of the study in the Business Week, that prove directly linkages between R&D expenditures and firm's success variables.

As mentioned above the whole model, respectively the hypothesis was examined on a sample of 49 larger companies, drawn from 13 industry groups.

The results are: RDE has impact on PROF, and the two technology variables TECST and TECCT have complementary impact on the firm's performance measured by the corporate PROF with controls for firm size (AST) and firm productivity (SEMP).

These results confirm the surveys and correlation analyses in the Business Week, that R&D spending has a positive impact on business success.

The overall assumption is: "*accumulation of knowledge and TECST resulting from R&D efforts contribute to the performance of the firm*." [5]

The authors propose, that "*the real impact of R&D expenditures is on TECCT and TECST*."[5] Furthermore the authors found that the lower the TECST and the higher the TECCT, the better is the firm performance. In addition to this the authors state: "*...the higher the SEMP and the larger the accumulated assets the higher is the firm's performance*."[5]

The results are well formulated, because the sample confirms the impacts and relations, which are described in the model.

In fact the authors are not going to eliminate the factor R&D expenditures, respectively R&D strategy, to the firm's success: "*Also, firm performance is causally related to more factors than just technology level*" [5].

A very good statement is the critics on their own metrics, as following: "*…these three measures are not exhaustive, ..*".[5]

In conclusion the paper wants to test, whether increased knowledge contributes to a performance of a company which was successful.

IV. Comparisons with other Researchers in the Related Fields and Contributions of this Paper

There is a lot of research done in this field to find out, how high is the correlation between several input and output variables, how to measure R&D performance, and how to define models for R&D strategy and their success.

Mitchell and Hamilton state: "*Major purpose of an R&D option is to influence the future investment favorably, either by lowering costs or by increasing returns*"[23]

A distinction between the individual project level and firm level on measuring R&D performance occur in the literature.

First it is necessary to summarize some research done on the R&D project level.

Cooper [16] presents 12 clusters of R&D performance, each composed of several subindexes. Within the clusters, the sample is divided into three groups: high, medium, and low scorers. The “important” clusters are identified as those with the largest difference in the percentage of successful projects between the high, medium, and low scorers. Then the clusters expressing a combination of R&D output, process, strategy, and external market conditions.

Zirger and Maidique [17] build on their own survey of 330 in new products in the electronic industry a framework of key capabilities for project success. In this study marketing and manufacturing functions are included.

Clark and Fujimoto ’s study of the world car manufacturer use three key R&D performance measures: engineering productivity, time to market, and total product quality. [18]

Pillai, Rao and Srinivasa [19] describing a new approach for the performance monitoring of R&D projects. They designed a graphic tool, named PACT, that consists of data base for time, cost and progress.

A broad list of metrics, how to measure the effects of R&D is shown in a study of Tipping, Zeffren and Fusfeld. Their metrics are referring to the project and company level of R&D. [21]

We can see there are different valuations of how to measure R&D performance. Here in this case the authors using TECCT and TECST as the variables to describe the performance of R&D. The variable which describes the firm’ s success is the variable PROF.

On the company level of R&D performance is also research done to examine R&D spending and the results on these expenditures.

Cordero [20] measures the output with quantitative monetary measures (revenue, rate of return, percent of new product sales, and business opportunities), quantitative nonmonetary measures (market share, number of new products, publications and patents), and qualitative measures (profile, subjective revues).

Griffin an Page identify 14 most widely used product performance measures and classify them into four categories, as customer acceptance, financial success, product and project success, and firm level measures.[25]

Brown and Gobeli using a list of 10 mostly preferred measures of R&D performance in seven categories. [26]

The prove of correlation between variables occur in the following articles.

Parasuraman and Zeren conclude that, “*...in general, R&D expenditures have fairly strong associations with profits and sales*,..” [6]. They mentioned also strong time-lag effects of R&D spending on sales: “*evidence is there of time lagged effects of R&D expenditures appears to indicate a stronger, and perhaps more meaningful, effect on sales than on profits.*”[6].

These lag effects are build in the research paper R12 by using RDE data from 1989, and using data for the other variables from 1991. This assumes the lag time for R&D expenditures of approximately 2 years, but do we know this when the R&D strategy has an impact on firm’s success? Pakes and Shankerman (1984) suggests, that firms expect revenue returns to R&D spending to begin within 1.2 and 2.5 years.[7]

This time lag is a real problem. If you use data, e.g., from 1990 for all variables for the prove of a correlation model, then you don’t prove a causal relation, even there is a strong correlation between variables. Due to the time lag it is necessary to use several data from years before to show in detail the impacts of the output variables from 1990. In this fact the paper is not a contribution, but is was not the aim of the authors to figure out the time lags in certain industry groups.

PIMS studies have shown that R&D/Sales is more often, and generally, more strongly, correlated with sales growth.[8]
Morbey found relationships between R&D expenditures and profit growth, but not in a generalizable way.[14]
He uses three levels of analysis: an industry composite analysis to show that R&D overall has increased steadily each year since 1981, a across industry analysis shows that only by examining high-research intensive industries (R&D) is a correlation between R&D intensity and profit growth, and across firm analysis within industries.
"*The relationship between R&D intensity of industries and profit growth is generally insificant*."[14]

In another study from 1990 Morbey and Reithner is proved that there is a very strong correlation between average R&D expenditure per employee and subsequent company profit margin and sales per employee.[15]

Brenner and Rushton [8] could not find a relationship indicating that above average R&D investors had prior above average sales growth, whereas sales growth is consistently related to prior R&D/Sales.

Szakonyi [22] concentrates entirely on the process proposing to measure R&D effectiveness by the presence and sophistication of formal procedures in 10 areas: project selection, planning, idea generation, quality control, people motivation, crossdisziplinary teams, cooperation with marketing, manufacturing, finance, and strategy.

Other researchers developed econometric models to predict corporate performance, with varying success.[12][13]

Some empirical generalizations from William Boulding and Richard Staelin are very interesting.[13] They state the following:

1) Investment in R&D leads to (causes) demand-side monopoly for firms that have either a good market position or an easy competitive environment (but not both)
2) A firm obtains excess returns from a strategic action (asset) when it has both ability and motivation advantageously use the asset
3) To assess the generalization of a strategic action on firm performance, requires, at least conceptually, within and across firms analyses.

Other researchers have drawn models which predict the performance of R&D expenditures.[9], [10]

The impacts of advertising and R&D expenditures are discussed in [10], [11], [24].
As a matter of fact the model applied by the authors is unique. According to their hypothesis, that the technological strength and knowledge contribute to the performance of the firm, and not only a certain amount of R&D spending. In this view the article is a milestone.

In conclusion to this the Research done in this field is not sufficient enough. There has to be more studies from an overall viewpoint, that means referring to the whole industry, and not only project cases and/or industry groups.

V. Strengths and Weaknesses of the Selected Article

The Strength of the research paper from C. Carls Pegels and M. V. Thirumurthy is the usage of statistical models to prove the above mentioned hypothesis.

The authors criticize the direct linkage of R&D expenditures, respectively R&D strategy and their impact on the performance of a firm. It is a strength of this article to try a new model of interdependencies as shown in Figure 1.

Furthermore are the results well-stated on the base of their findings in the sample-data. As a matter fact the article is a contribution to the study of the business week, because the model in the research paper recommend the findings of the business week. The usage of metrics for the variables TECCT and TECST delivers the chance to quantify the impacts. Only with a clear definition of these variables, what was done in the paper, is a evaluation of a model possible.

In addition to the measurable variables the authors use proxy variables: SEMP and AST to ensure that the results are not affected firm size and productivity.

The variable annual operating income is chosen, because it defines the net income and is not biased if you would chose profit per employee.

The weaknesses of the paper arise from the definition of the technological strength (TECST), which is defined in this paper as the number and the current impact index of the firm' patents. The patent impact index is criticized by Foster: *"...we have found that relatively few of our patents produce a large business impact"*.[2]

Furthermore is the variable TECCT defined by the medium age of the U.S. patent references cited in the company's new patents. The lower the number, the more quickly the company is replacing one generation of invention with another. Here is technological cycle time expressed through the usage of the changing inventions, but as it is already known invention maybe not always contribute to innovation.

Another weakness is the small sample size of only 49 "larger" companies. Note that sample size (n) and the number of predictors (k) are two crucial factors which determining how well a given equation will cross-validate (i.e. generalize). The n/k ratio is the crucial issue. For small ratios (5:1) or less the shrinkage in predictive power can be substantial. A study by Guttman (1941) illustrates this point.[1] In addition to the small sample size there maybe arise problems by making a sample from 13 industry groups with a sample size of 49. Notice, then you are examining from each group only 3-4 candidates. That can cause a great bias, resulting in a different T-Statistic with varying significance levels from the first sample, if you are going to make a second sample with the same preconditions.

This research paper from Pegels and Thirumurthy is a contribution to the research in the field of the R&D strategy of companies and their impacts. The paper is consistent in stating the issues and presenting the results. Nevertheless that there are some critics the paper is a further step in examining the issue R&D. In fact the article is a path for other researchers to prove the two-step model in a broader way, means increasing the sample size.

The problem we are faced by measuring impacts of R&D spending on firm's success is the different usage of success variables in the literature. Furthermore arise problems how to measure R&D productivity and how are the causal relations between the variables, as you can see from the different usage of metrics in the past research in this field.

If you use statistical models then it is always necessary o take care of the causality.

Causality is the great obstacle, that cannot be proved by application of statistical methods. Causality can only be a result of logical thinking.

Furthermore arise time lag problems. How to handle this? There is always an lag in the statistical data to build in. That means if you are proving data, which expresses the success variable of a company, e.g. profit/employee, so you have to consider that R&D efforts from a former period causes this output variable.

As already mentioned the authors used a time lag of 2 years.

VI. Future Research Fields for Unanimity about R&D Efforts and their Impacts

The goal is to achieve unanimity in the field of R&D about the effects and impacts by using a certain R&D Strategy, and what should be the implications for a manager who is involved in the field R&D.

Future research fields might be using a model with variables, which might have an impact on business success, not only the R&D strategy. This will be very difficult, to create a holistic model which can show, which part plays the R&D spending on the overall business success.

One thing is already clear and statistical proved: the R&D spending has a positive impact on business success, if this impact is not decreased through other variables that might have been a greater part to the business success. For instance marketing activities of a company play a great role to act successfully against the competitors. If these expenditures in marketing were ineffective, the negative effect on the business success is unavoidable.

The usage of consistent models is necessary. The overall problem is to get quantitative measures. For the variables TECCT and TECST, it was the number and influence of patents from a company. In fact it is indispensable to define the right output variable. That means what kind of metrics is used to measure the success, respectively effectiveness of R&D strategy. This could be the annual operating income (PROF).

In conclusion to the paper of the authors it is sometimes necessary to narrowing the research field under certain assumptions, that means you cannot have all results from the matter R&D within one work. Research needs time to get good results, and that is often a further problem.

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