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RELATIONSHIPS BETWEEN R&D AND PROFITABILITY: AN EXPLORATORY COMPARISON OF TWO BUSINESS SIMULATIONS WITH TWO REAL-WORLD TECHNOLOGY INTENSIVE INDUSTRIES

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ABSTRACT

The purpose of this study is to provide an exploratory framework for analysis that can be used in future studies. Some of the relationships between R&D and profitability between two business simulations and two industries were used to illustrate this framework. This study explores whether R&D: profitability relationships are the same in two industries and in two simulations. The R&D: profitability relationships for each of the four settings are examined first. The results show similarities in R&D: profitability between the two industries. For the two simulations, an equal number of similarities and differences were identified when comparing R&D and profitability. Finally, the core issue is addressed; do the BSG and MMG simulations reflect the same R&D: profitability relationships as two real world, technologically intensive industries? In most instances, the simulations do not. Questions for further exploration are then identified.

INTRODUCTION

One of the uses of simulations is to illustrate concepts and reinforce relationships between variables. For example, to reinforce the idea that profitability is good, business simulations reward higher profitability with higher scores. Many other relationships are embodied within simulations such as higher advertising or higher quality products able to command higher prices. Some of these relationships are accounting-based, while others are generally accepted.

Simulations must accurately reflect accounting and operating relationships, such as $MARGIN \times TURNOVER = RETURN \text{ ON ASSETS}$. Nor, would many argue that increased product quality is associated with increased price (*ceteris paribus*) in the real world. Simulations explicitly, and by design, reflect this type of generally accepted relationship. However, more complex, less straightforward relationships also exist in real world and simulated businesses. For example, the relationship between R&D and profitability is not uniform across industries (House & Fries, 1992).

The purpose of this study is to provide an exploratory framework for analysis that can be used in future studies. Some of the relationships between R&D and profitability between two business simulations and two industries were used to illustrate this framework. It addresses the questions "What are the relationships between R&D and profitability in each of the four settings?" The next question asked is, "Are the relationships the same in each setting?" Those results are then used to compare the relationships in both simulations with the two industries.

RESEARCH AND DEVELOPMENT AND PROFITABILITY

Considerable attention has been devoted to measurement of the level of research and development activity and its relationship to profitability. The relationship between R&D outlays and profitability has been emphasized by Grabowski & Mueller (1988), Hirschey (1982), and Roberts & Hauptman (1987). Branch's (1974) study of seven industries found that changes in R&D outlays were significantly related to changes in profits. Schoeffler (1977) determined that high R&D outlays are negatively correlated with profits if the market is growing rapidly and that R&D outlays have

a positive effect on performance only if the firm is in a strong position to begin with.

A recent study of 727 companies for years 1983 to 1987 found that R&D intensity (i.e., R&D outlays/sales revenues) did not correlate significantly with return on sales or return on assets (Morbey & Reither, 1990). A weak relationship between research intensity and profit growth was found in computer, paper and machinery industries. In contrast, a study of growth, productivity, and profitability measures for twenty-six consumer durable manufacturing companies, twenty-six nondurable consumer products manufacturing, and twenty producer durables companies for 1991 found R&D/sales and R&D employee positively related to return on assets for the nondurable consumer companies and negatively related to return on assets for the producer durables companies (House & Fries, 1992).

R&D\$/Employee may be a better measure of research activity in many instances since the number of employees has less short term variability than sales revenue. In a study of 134 companies (1978-1987), R&D/employee was found to be positively correlated with profit margin and sales per employee but not return on assets while R&D\$/sales revenue was not correlated with return on sales, return on assets, or sales/employee (Morbey & Reithner, 1990). Grilches (1987) found that the level of R&D activity contributes significantly to productivity growth in larger U.S. manufacturing companies.

METHODOLOGY

In order to assess the extent simulations model real world effects, simulation results were compared with those for twenty-six computer hardware companies and twenty-four pharmaceutical companies for 1990. The two actual industries selected are among those considered to fall in the technology intensive category and can be expected to emphasize research and development efforts. Although it can be argued that simulation results should only be generally representative of real world outcomes, the extent to which simulation results differ from actual industry results at least gives a benchmark measure of their realism and validity.

Independently, data was collected for two years for twenty-nine companies playing the Business Strategy Game (BSG) and twenty-eight companies playing a modified version of the Multinational Management Game (MMG). Both simulations are moderately complex, involving significant R&D decisions, as well as all major functional areas, including marketing, production, finance, and personnel. Quarterly data was aggregated in the MMG to permit comparisons on an annual basis with BSG.

CORRELATION RESULTS-A COMPARISON OF THE IMPACT OF KEY R&D VARIABLES ON PROFIT MEASURES FOR THE TWO INDUSTRIES

The first issue addressed is whether R&D: profitability relationships are the same in two industries. In a previous study of the lagged effects of productivity and R&D variables on profitability, twenty-six computer hardware/peripheral companies and twenty-four pharmaceutical companies were selected from BUSINESS WEEK--1991 and R&D SCOREBOARD--1990 (House & Fries, 1991). The R&D variables were correlated with return on sales and return on assets for year one and year two. As Table One shows, for the computer hardware companies,

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TABLE ONE

**COMPUTER HARDWARE COMPANIES
R&D: PROFITABILITY RELATIONSHIPS**

| R&D VARIABLES | ROS | ROA | ROS | ROA |
|---------------------|--------|--------|--------|--------|
| | YEAR 1 | YEAR 1 | YEAR 2 | YEAR 2 |
| R&D \$/SALES REVS-1 | 0.28 | 0.12 | -0.13 | 0.15 |
| R&D \$/EMPLOYEE-1 | 0.39* | 0.29 | 0.33 | 0.44 |

*P,0.05
N=26

R&D/employee is positively correlated with return on sales in year one and return on assets in year two.

As Table Two shows, for the pharmaceutical group R&D/sales is positively correlated with return on sales and return on assets for both years but R&D/employee is positively correlated with return on sales and return on assets only in year two.

**TABLE TWO
PHARMACEUTICAL COMPANIES
R&D: PROFITABILITY RELATIONSHIPS**

| R&D VARIABLES | ROS | ROA | ROS | ROA |
|---------------------|--------|--------|--------|--------|
| | YEAR 1 | YEAR 1 | YEAR 2 | YEAR 2 |
| R&D \$/SALES REVS-1 | 0.62 | 0.45* | 0.71 | 0.56 |
| R&D \$/EMPLOYEE-1 | 0.35 | 0.17 | 0.68* | 0.60 |

*P,0.05
N=24

Research intensity (i.e., R&D/sales revenues) does not seem to significantly affect profitability in the computer hardware industry, but R&D/employee affects current year return on sales and lagged year return on assets. In the pharmaceutical industry, research intensity has both a current year and lagged year impact on profitability but R&D/employee is positively related to profitability only on a lagged basis. It appears that there are significant differences in the impact of productivity and R&D variables on an industry by industry basis.

Computer and Pharmaceutical Industries Compared

A comparison of Tables One and Two is shown in Figure One. The computer and pharmaceutical industry samples both showed a positive correlation between all of the profitability and R&D measures except one. However, none of the statistically significant relationships are the same for both industries. This supports prior studies that suggest industry differences in the relationships between R&D and profitability (House and Fries, 1992). The next question is "what are the relationships between R&D and profitability in business simulations?" Only then will it be possible to ask whether simulations reflect the same relationships as real world industries.

FIGURE ONE

**COMPUTER AND PHARMACEUTICAL INDUSTRIES'
R&D: PROFITABILITY RELATIONSHIPS COMPARED**

| COMPUTER INDUSTRY | PHARMACEUTICAL INDUSTRY | |
|----------------------|----------------------------|-------------|
| | R&D/ SALES | R&D/ EMP |
| ROS-1 | # | # |
| ROA-1 | # | # |
| ROS-2 | ? | # |
| ROA-2 | # | # |

Both significant @ .05 with the same direction of correlation
Both same direction of correlation
? Different direction even though both may be significant @ .05

**CORRELATION RESULTS—A COMPARISON OF THE IMPACT
OF KEY R&D VARIABLES ON PROFIT MEASURES
FOR THE TWO SIMULATIONS**

Table Three shows the relationship of the and R&D variables on the Income measures for the BSG companies

**TABLE THREE
BUSINESS STRATEGY GAME COMPANIES
R&D: PROFITABILITY RELATIONSHIPS**

| | ROS YEAR | ROA YEAR | ROS YEAR | ROA YEAR |
|--------------|-------------|-------------|-------------|-------------|
| R&D \$/SALES | -0.17 | -0.32 | -0.54 | -0.56 |
| R&D | 0.23 | 0.22 | 0.04 | 0.02 |

* P<0.05
N=29

R&D expenses/sales revenues for year one is negatively and significantly related to return on sales and return on assets for year two but not for year one. R&D/employee is not significantly related to any of the income measures used in this study. Thus, it appears that research and development outlays have a lagged negative impact on profitability and such outlays and may even take longer than one year to pay off. Therefore, teams that go overboard on R&D outlays early in the game may not see the payoff from these actions during a normal period of play.

Table Four shows the R&D: Profitability relationships for the Multi national Management Game companies.

R&D/sales revenue is negatively and significantly correlated with return on sales for year one is borderline negatively correlated with return on sales for year two. R&D/employee is negatively and significantly correlated with return on sales for years one and two. As is the case with R&D/sales revenues, the impact on return on assets is less significant than the effect on return on sales. Thus, increasing R&D levels faster than sales volume increases will depress profitability on a

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TABLE FOUR

MULTINATIONAL MANAGEMENT GAME COMPANIES
R&D: PROFITABILITY RELATIONSHIPS

| R&D VARIABLES | ROS | ROA | ROS | ROA |
|-------------------|--------|--------|--------|--------|
| | YEAR 1 | YEAR 1 | YEAR 2 | YEAR 2 |
| R&D \$/SALES-1 | -0.38* | -0.35 | -0.36 | -0.25 |
| R&D \$/EMPLOYEE-1 | -0.46 | -0.38 | -0.45 | -0.30 |

- P<0.05
- N = 28

current year basis and to a lesser extent on a lagged year basis. Increasing R&D levels at a faster rate than employee levels increase will negatively impact return on sales and return on assets in year one and return on sales in year two.

As previously noted, in the BSG, R&D/sales is negatively related to return on sales and return on assets in year two but not in year one. It appears that increasing debt has a negative current year impact on profitability and increasing R&D outlays has a lagged negative impact on profitability which suggests that companies in this game should be careful to avoid excessive use of debt or R&D spending early in the simulation if they wish to meet profit goals.

In the MMG, R&D/sales and R&D/employee have a negative impact on return on sales in year one. R&D/employee has a negative effect on year two return on sales. Since R&D expands/sales, and R&D/employees are negatively related to year one return on sales, and year one return on sales is highly positively correlated with year two return on sales and return on assets, these variables would seem to have an indirect negative impact on profitability. Therefore, increasing sales volume in relation to assets and R&D levels in relation to sales volume or number of employees too rapidly could hinder accomplishment of company profit goals.

BSG AND MMG COMPARED

A comparison of Tables Three and Four is shown in Figure Two.

FIGURE TWO

BUSINESS STRATEGY GAME AND MULTINATIONAL
MANAGEMENT GAME R&D: PROFITABILITY
RELATIONSHIPS COMPARED

BUSINESS STRATEGY GAME

| MULTINATIONAL MANAGEMENT GAME | R&D/ SALES | R&D/ EMP |
|-------------------------------------|---------------|-------------|
| | ROS-1 | # |
| ROA-1 | # | ? |
| ROS-2 | # | ? |
| ROA-2 | # | ? |

* Both significant @ .05 with the same direction of correlation

Both same direction of correlation

? Different direction even though both may be significant @ .05

The Business Strategy Game and the Multinational Management Game companies experienced some similar and some different relationships between profitability and R&D. The correlations were in the same direction, but none significant, for R&D/Sales and the profitability measures, but in the opposite direction between R&D/Employee and the profitability measures. This suggests that the two simulations illustrate different relationships between R&D expenditures and profitability.

The experience of the computer and pharmaceutical industries, though similar, showed differences. The two business simulations also had similarities and differences. The evidence suggests that in real world industries and in simulations, the relationships between R&D and profitability are not the same. These results allow us to now address the question, which is the point of this study. To what extent do the two simulations illustrate the same relationships between R&D and profitability as the two industries?

INDUSTRY AND SIMULATION RESULTS COMPARED

A comparison of the industries' experience and the simulation companies' experience is shown in Figure Three. The Business Strategy Game companies experienced a positive relationship between R&D/Employee, as did both industries, so to that extent, the BSG illustrates similar R&D: profitability relationships as the industries. However, the BSG's R&D/Sales was similar to the industries' in only one instance. To that extent, the BSG illustrates opposite the R&D: profitability relationship of the two industries.

In fifteen of the sixteen comparisons, the Multinational Management Game companies experienced relationships opposite both industries in terms of R&D: profitability. Only the R&D/sales: return on sales for year two relationship is the same for the MMG and the computer industry.

The results of this study therefore suggest that the MMG does not illustrate the same R&D: profitability relationships, while the BSG only illustrates some of the same R&D: profitability relationships as the computer and pharmaceutical industries.

CONCLUSIONS AND DISCUSSION

This study provided an exploratory framework for analysis that can be used in future studies. This study explored whether R&D: profitability relationships were the same in two industries and in two simulations to illustrate this framework. The R&D: profitability relationships for each of the four settings were first examined (Tables 1, 2,3,4). The results showed mostly similarities between the two industries and an equal number of similarities and differences between the two simulations (Figures 1 & 2). Finally, the core issue was addressed; do the BSG and MMG simulations reflect the same R&D: profitability relationships as two real world, technologically intensive industries? In most instances, the simulations do not (Figure 3).

To the extent simulation companies fail to experience exactly the same relationships as real world industries, does that mean the simulations are in error? Does it mean they teach relationships between variables that are different from reality? How important is it that more complex realities be accurately reflected by simulations?

Questions have been raised and issues to be answered have been identified as a result of this study. The relationships between R&D and profitability need to be examined for more industry settings and more simulations. Different measures of R&D as well as profitability could be explored. Different lag times between R&D expenditures and profitability could be tested. A survey of business simulation users could identify the extent venous relationships are viewed as important. Other important relationships should than be explored to determine whether they are accurately reflected in simulations. Some of those include comparisons of R&D with sales or market value. Longer lagged time

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FIGURE THREE

| BUSINESS STRATEGY GAME | | | | MULTINATIONAL MANAGEMENT GAME | | |
|--------------------------------|-----------|---------|---|-------------------------------|---------|---|
| | R&D/SALES | R&D/EMP | | R&D/SALE | R&D/EMP | |
| COMPUTER INDUSTRY | ROS-1 | ? | # | ROS-1 | ? | ? |
| | ROA-1 | ? | # | ROA-1 | ? | ? |
| | ROS-2 | # | # | ROS-2 | # | ? |
| | ROA-2 | ? | # | ROA-2 | ? | ? |
| PHARMA CEUTICAL INDUSTRY | ROS-1 | ? | # | ROS-? | ? | ? |
| | ROA-1 | ? | # | ROA-1 | ? | ? |
| | ROS-2 | ? | # | ROS-2 | ? | ? |
| | ROA-2 | ? | # | ROA-2 | ? | ? |

* Both significant @ .05 with the same direction of correlation
 # Both same direction of correlation
 ? Different direction even though both may be significant @ .05

frames might also show different relationships. Direct industry comparisons provide another way to improve this study.

This study raises more questions than it answers. However, it suggests new directions for research linking simulations and the complex world they are intended to represent, and to estimate how important that is in the purpose of simulations as teaching devices. Simulations have contributed to vary valuable learning experiences.

Perhaps they can be even more affective in the future as answers to the questions raised by this study are addressed.

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