

EFFECT OF MARKET SHARE AND PRODUCTION EXPERIENCE ON COMPANY PROFITABILITY

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ABSTRACT

The effect of market share and production experience on company profitability was studied using data from 94 firms of a computer-assisted business gaming simulation that had advanced through 338 periods. Strong correlations are observed between market share and profitability. Somewhat weaker correlations are observed between production experience and profitability. Both market share and production experience are of strategic importance, but market share has a stronger effect because it is more direct. The results validate both strategy theory and business simulations.

INTRODUCTION

The centrality of profit as the measure of company performance is well established, even considering Teach's (1990) point that profit is a short-term measure whose use may inappropriately encourage short-term thinking. Clearly, profit is a bottom-line measure, which may nevertheless be supplemented by forecasting accuracy and other measures, such that those that Kaplan and Norton (1992, 1996) incorporated into their Balanced Scorecard model, a model that Dickinson (2003, 2004) and Kallás and Sauaia (2004) recently studied in gaming-simulation applications. Accordingly, profit's central role in the measurement of firm performance justifies the careful examination of this measure in a variety of settings, simulated and real.

Previous studies (Patz, 1999, 2000; Peach & Platt, 2000; Thavikulwat & Pillutla, 2004) have shown that firm profitability in the earlier periods of a gaming-simulation run is predictive of its profitability in later periods. A study by Faria and Wellington (2004a) found profitability to be correlated with market share, but generally at a moderate level ($0.30 < r < 0.50$), contrary to the strong correlation level ($r \geq 0.50$) that they had expected from studies by Buzzel and Gale (1987) using everyday-world data drawn from the well-known PIMS database. In explaining their unexpected results, Faria and Wellington pointed to measurement issues, noting particularly that correlations were higher when dollar revenues rather than unit sales were used as the basis for computing market shares.

PURPOSE

This study extends Faria and Wellington's (2004a) research by asking whether the correlation between profitability and market share might be stronger if the simulation experience was more competitive and was administered over many more periods, which would require a simulation of a different design. Faria and Wellington studied simulations of manufacturing firms in oligopolistic industries averaging 4.6 firms per industry that were administered over 12 periods (A. J. Faria, personal communication, September 22, 2004), the midpoint of the 8- to 12-period range that Anderson and Lawton (1992) found to be common for computer-controlled (Crookall, Martin, Saunders, & Coote, 1986), administrator-driven business simulations. Administering that kind of simulation for many more periods would neither be pedagogically useful (Rollier, 1992) or administratively practical within a typical college term, but these limitations do not hold for computer-assisted clock- and activity-driven simulations (Thavikulwat, 1996). For simulations of this ilk, a simulation time period can elapse within an hour or less, so within the typical college term, the entire experience can easily encompass several hundred periods. Although advanced simulations of this kind are uncommon, technological progress will inevitably make them more widely available over time. Moreover, the real-world studies that justified Faria and Wellington's work were not based on new entrants, but on long established companies that had survived for the real-world equivalent of many decision periods.

Besides extending Faria and Wellington's (2004a) work, this study adds a second dimension. It considers the extent to which the experience curve (Henderson, 1984) is predictive of profitability. Interest in the strategic role of the experience curve predates Buzzell and Gale's work (1987) by over a decade. And although Buzzell and Gale concurred with Kiechel (1981) in their disparaging assessment of that concept, the experience-curve concept is still covered in textbooks on strategic management, is one of the four perspectives of the Balanced Scorecard model, and remains an important element of Krugman's (1981) and Lancaster's (1980) generally accepted strategic rivalry theory of intra-industry trade.

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MARKET SHARE

The mathematical relationship between profitability and market share explains several statistical observations. To measure profitability, Faria and Wellington (2004a) used earnings per share (EPS), which is different from Buzzell and Gale's pretax-return-on-investment measure, but which nevertheless is sensible considering that Faria and Wellington's measurement was taken over the lifetime of each firm whereas Buzzell and Gale's was taken over the most recent four years. Moreover, Faria and Wellington used two measures of market share, dollar market share (DMS) and unit market share (UMS).

Earnings per share is related to after-tax income (ATI) and the number of shares outstanding (NSO) as follows:

$$\text{EPS} = \frac{\text{ATI}}{\text{NSO}} \quad (1)$$

Revenue (REV) is related to dollar share and dollar market size (DMZ) as follows:

$$\text{REV} = \text{DMZ} \times \text{DMS} \quad (2)$$

After-tax profit is related to revenue, operating cost and expenses (OPE), and other income and expenses (OIE) as follows:

$$\text{ATI} = \text{REV} - \text{OPE} + \text{OIE} \quad (3)$$

Combining Equations 1 and 2 into Equation 3 gives rise to

$$\text{EPS} = \frac{\text{DMS} \times \text{DMZ}}{\text{NSO}} + \frac{\text{OIE} - \text{OPE}}{\text{NSO}}, \quad (4)$$

which, when rearranged becomes

$$\text{EPS} = \left(\frac{\text{OIE} - \text{OPE}}{\text{NSO}} \right) + \left(\frac{\text{DMZ}}{\text{NSO}} \right) \times \text{DMS} \quad (5)$$

Equation 5 has the form of a simple linear regression of DMS on EPS, that is, it is of the form

$$\text{EPS} = \alpha + \beta \times \text{DMS} + \varepsilon \quad (6)$$

Correlations and regressions are equivalent statistical methods (Draper & Smith, 1966). Thus, the statistical significance of a Pearson correlation between EPS and DMS is the same as the statistical significance of the regression parameter, β , in Equation 6, where α and β approximate the quantities $(\text{OIE} - \text{OPE})/\text{NSO}$ and DMZ/NSO , both as given in Equation 5, respectively. The closeness of the approximation, and therefore the strength of the correlation between EPS and DMS, depends upon the two quantities

being independent of each other and of DMS. Inasmuch as NSO is the denominator of both terms, to the extent NSO is variable the two will not be independent. This should explain Faria and Wellington's (2004a) observation of moderate correlations between profitability and market share, instead of the strong correlations that they had expected.

The dependence of the two quantities on each other can be resolved by multiplying both sides of Equation 5 by NSO, arriving at the following equation:

$$\text{ATI} = (\text{OIE} - \text{OPE}) + (\text{DMZ}) \times \text{DMS} \quad (7)$$

This latter equation has the form of a simple linear regression of DMS on ATI, thus of the form:

$$\text{ATI} = \alpha' + \beta' \times \text{DMS} + \varepsilon' \quad (8)$$

In the form of a null hypothesis, the argument presented is as follows:

Hypothesis 1: The correlation between ATI and DMS will not be higher than the correlation between EPS and DMS.

The fit of Equation 8 to the data in a simple regression of DMS on ATI will be better, and therefore the Pearson correlation between the two will be higher, if the quantity, $\text{OIE} - \text{OPE}$, is less variable, because α' , which approximates the quantity, is assumed to be constant. Inasmuch as OIE is a source of variability, it can be moved to the left side of the Equation 7 for a better fit. Operating income (OPI) relates to ATI and OIE as follows:

$$\text{OPI} = \text{ATI} - \text{OIE} \quad (9)$$

Accordingly, Equation 7 can be redefined as follows:

$$\text{OPI} = (-\text{OPE}) + (\text{DMZ}) \times \text{DMS} \quad (10)$$

The null hypothesis of this argument is as follows:

Hypothesis 2: The correlation between OPI and DMS will not be higher than the correlation between ATI and DMS.

Faria and Wellington (2004a) also observed that the Pearson correlation between EPS and DMS was higher than the correlation between EPS and UMS. This result can be explained mathematically also. The relationship between REV and UMS is more complicated than the relationship between REV and DMS, because the former relationship includes average product price (PRICE) in addition to UMS, as follows:

$$\text{REV} = \text{PRICE} \times \text{UMZ} \times \text{UMS} \quad (11)$$

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When the right-hand side of Equation 11 is substituted for REV in Equation 3 and re-arranged in the manner of Equations 4 and 5, the result is as follows:

$$\text{EPS} = \left(\frac{\text{OIE} - \text{OPE}}{\text{NSO}} \right) + \left(\frac{\text{PRICE} \times \text{UMZ}}{\text{NSO}} \right) \times \text{UMS} \quad (12)$$

PRICE tends to be inversely related to UMS, because higher product prices tend to result in lower sales volumes, hence lower unit market shares. Thus, (PRICE \times UMZ)/NSO, the coefficient of UMS in Equation 12, instead of being relatively constant and therefore approximated by the estimate of β in a regression of UMS on EPS, will instead be more variable. For this reason, the Pearson correlation between EPS and UMS will be lower than the correlation between EPS and DMS, which is what Faria and Wellington (2004a) observed.

Similarly, substituting for the rightmost term in Equation 7 transforms it into the following:

$$\text{ATI} = (\text{OIE} - \text{OPE}) + (\text{PRICE} \times \text{UMZ}) \times \text{UMS} \quad (13)$$

Likewise, Equation 10 can be transformed as follows:

$$\text{OPI} = (-\text{OPE}) + (\text{PRICE} \times \text{UMZ}) \times \text{UMS}. \quad (14)$$

Accordingly, applying the same argument to ATI (Equation 7 vs. Equation 13) and OPI (Equation 10 vs. Equation 14) as to EPS (Equation 5 vs. Equation 12) gives rise to the following null hypotheses:

Hypothesis 3: The correlation between ATI and UMS will not be lower than the correlation than the correlation between ATI and DMS.

Hypothesis 4: The correlation between OPI and UMS will not be lower than the correlation than the correlation between OPI and DMS.

EXPERIENCE CURVE

The relationship between production experience and profitability is more complicated. A precise mathematical model of how production experience affects labor hours has existed for some time, and is credited to work done in 1925 by Miguel Reguero, commander of the Wright-Patterson Air

Force Base in Dayton, Ohio (Gaither, 1994). In this classic model, production labor hours fall by a fixed percentage (ϕ) at every doubling of production experience (x). Thus, if the fixed percentage is 80% and if the first unit produced (T_1) required 100 hours, the second (T_2) would require 80 hours (80% of 100); the fourth (T_4), 64 hours (80% of 80); the eighth (T_8), 51.2 hours (80% of 64), and so forth. The continuous form of the model, with T_x representing the x th unit, is as follows:

$$T_x = T_1 x^{\log_2 \phi}. \quad (15)$$

The effect of saving labor hours on firm profitability is complex. It depends upon management's flexibility with respect to labor, the extent to which production is constrained by other considerations, and management's ability to manage successfully a higher volume of production. If labor cost is fixed, because of legal requirements, management policy, and the like, and if furthermore production is constrained by demand or other resource bottlenecks, then saving labor hours will have no effect on firm profitability. If labor cost is fixed but production is unconstrained, then production capacity increases, which can affect profitability through higher sales. If labor cost is variable but production is constrained, then the savings will raise firm profitability through a reduction in average production cost. If labor cost is variable and production is unconstrained, then the effect on firm profitability can be multiplicative, affecting both the cost of production and capacity. These relationships are summarized in Table 1.

Moreover, production experience can give rise to savings in other resources, such as energy, materials, equipment, space, and administrative overhead, so the concept can be generalized. Although the parameter and form of the experience-curve function may vary depending upon the resource and the industry, using a single curve to model the aggregate effect of production experience on firm profitability is the essence of Henderson's (1984) conception of the experience-curve principle.

Even so, applying the curve to the aggregate effect does not override the essential point of Table 1, which is that production experience can lower production cost only to the extent that reduced usage of production resources gives rise to lower production cost, and that it can raise production capacity, which is an effect not on profitability directly, but on the potential for increased profitability. A schematic diagram of the two possible effects is shown in Figure 1.

TABLE 1
EFFECT OF LABOR-HOUR SAVINGS ON FIRM PROFITABILITY

Condition		Effect of Labor-Hour Savings on Profitability
Flexible Labor?	Constrained Production?	
No	Yes	None
No	No	Higher production capacity
Yes	Yes	Lower average production cost
Yes	No	Higher production capacity and lower average production cost

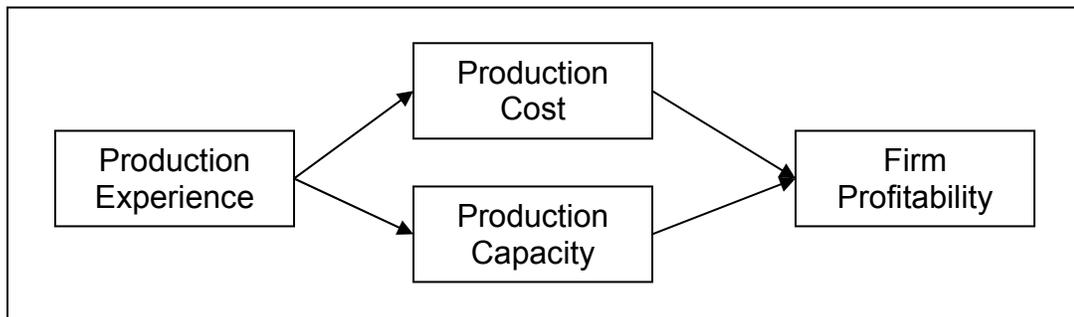


FIGURE 1
EFFECT OF PRODUCTION EXPERIENCE ON FIRM PROFITABILITY

Accordingly, the experience-curve effect should be greater in manufacturing industries, where a relatively large component of production cost is variable, than in service industries, where a relatively large component of production cost is fixed, but the correlation between production experience and firm profitability will nevertheless be less than the correlation between market share and profitability, because the relationship between production experience and firm profitability is less direct. The null hypotheses of these arguments are as follows:

Hypothesis 5: The correlation between ATI and x will be no higher in manufacturing industries than in the service industry.

Hypothesis 6: The correlation between OPI and x will be no higher in manufacturing industries than in the service industry.

Hypothesis 7: The correlation between ATI and x will be no lower than the correlation between ATI and DMS in all industries.

Hypothesis 8: The correlation between OPI and x will be no lower than the correlation between OPI and DMS in all industries.

METHOD

The data for this study came from simulated companies founded by 60 undergraduate business students enrolled in two sections of an international-business course at a comprehensive university. The gaming simulation package was GEO, a computer-assisted clock- and activity-driven simulation (Thavikulwat, 2004) of a global economic environment. Three nations made up this environment. As the participants registered themselves into the simulation, the computer program assigned each to the lowest-population of the three nations.

The exercise advanced through 338 periods segmented into 11 phases that were spread over 14 weeks. Each of the first 9 phases took place in one week, with participants allowed to migrate from one nation to another beginning with the fourth phase. At the conclusion of the exercise, the number of participants in the three nations, named North, South, and East, were 20, 19, and 21, respectively.

Beginning with the second phase of the exercise, participants were able to found companies whenever they

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wished, provided they had sufficient funds to pay the founding fee when it was required. Thus, unlike traditional computer-controlled simulations used in business education, participants were not given companies to manage from the start of the exercise and assigned to management teams. Instead, each participant received a periodic income that each could save or use to invest in a business, and to consume the products produced by the businesses that were created. Participants received points for products they consumed, which is how their performance was scored.

The number of companies each participant was allowed to found increased from one in the second phase to five in the eighth phase, but as each founded company also could found five subsidiary companies and each subsidiary company could found another five companies and so forth without limit, the actual number of companies that a participant could be responsible for founding was unlimited. The companies founded fell into three industrial sectors: service, single-resource manufacturing, and multiple-resource manufacturing.

Companies in the service sector all produced service units that were identical. Each service unit was worth 1 point when consumed. These companies required no resource for their production process. The number of service units each service company could produce in a period, that is, its production capacity, was constrained by a limit conforming to a 98% experience curve, calculated using the well-accepted learning-curve formula (Gaither, 1994).

Companies in the single-resource manufacturing sector produced material units, energy units, and chemical units. These products were assigned point values that varied by product and nation, ranging from 3 to 6 points when consumed. Each of these firms could produce products of only a single line, but regardless of which line the firm produced, the production process required service units, which the service companies supplied. The firm's production capacity increased in steps depending upon the

number of participant-executives it employed, moderated by its production experience in accordance with an experience curve of either 91.5% or 98%, depending upon the firm's product line and nation. The firm's resource requirement conformed to an experience curve of 98%.

Companies in the multiple-resource manufacturing sector produced food units only. These were worth 40 points each when consumed. The required resources for production were material, energy, and chemical units supplied by the single-resource manufacturing firms. A schematic diagram of a food company's supply chain is given in Figure 2. As with single-resource firms, the capacity of multiple-resource firms increased in steps depending upon the number of participant-executives employed, moderated by an experience curve of 98%. Resource requirements conformed to an experience curve of either 91.5% or 98%, depending upon the resource and the supplying firm's nation.

Accordingly, every participant was necessarily a consumer, because each participant earned points based on that participant's consumption. Service, material, energy, and chemical products could be sold either to consumers or to downstream firms. Food, however, could be sold to consumers only.

The numbers of companies founded and productive, by industry sector, product line, and nation are given in Table 2. As the table shows, participants founded many companies that were not productive, that is, companies that produced nothing. A company would be nonproductive if the founder did not proceed to buy shares in the company after having founded it. It also would be nonproductive if it was a manufacturing company that either did not employ participant-executives or did not acquire the resource units needed for its production process. These nonproductive companies and two manufacturing firms that had bought back all their outstanding shares (a material and an energy company in South) were excluded from the study.

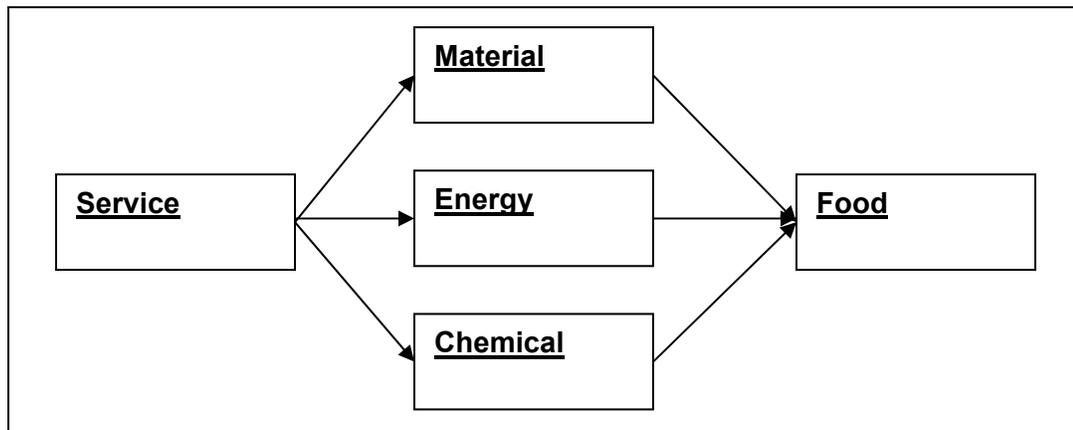


FIGURE 2
SUPPLY CHAIN OF FOOD COMPANY

TABLE 2
NO. OF COMPANIES FOUNDED AND PRODUCTIVE BY INDUSTRY SECTOR, PRODUCT,
AND NATION

Industry Sector	Product Line	Nation					
		North		South		East	
		Founded	Productive	Founded	Productive	Founded	Productive
Service	Service	29	24	27	21	27	23
Single-Resource Manufacturing	Material	6	2	3	1	8	5
	Energy	10	5	9	4	7	2
Multiple-Resource Manufacturing	Chemical	8	5	3	2	2	1
	Food	1	0	2	1	2	0

Thus, data from a total of 94 simulated companies across five competing industries were used in this study. These companies were grouped into two categories, 68 in the service category and 26 in the manufacturing category. Participants, as customers, could purchase the products of any company in any industry to advance their scores. Compared with Faria and Wellington's (2004a) study where the average industry had 4.6 companies and where companies did not compete for customers across industries, the level of competition in this gaming simulation is much higher.

RESULTS

The partial Pearson correlation matrix of profitability measures (EPS, ATI, and OPI), market-share measures (DMS and UMS), and production experience measure (x) of the companies studied, controlling for nation, is given in Table 3. The control for nation is necessary because each nation had its own currency, so the profitability measures of a company in one nation are not directly comparable with those of a company in another nation. Moreover, the relative values of currencies were unstable, ranging from an even 1 to 1 across all nations at the start to a maximum disparity of 3.375 to 1 in Period 152 of the 338-period exercise.

TABLE 3
PARTIAL PEARSON CORRELATIONS CONTROLLING FOR NATIONS

	DMS		UMS		x	
	Service†	Manufacturing‡	Service†	Manufacturing‡	Service†	Manufacturing‡
EPS	0.115 (0.356)	0.785** (0.000)	0.162 (0.195)	0.607** (0.002)	0.065 (0.604)	0.609** (0.002)
ATI	0.612** (0.000)	0.910** (0.000)	0.571** (0.000)	0.804** (0.000)	0.388** (0.001)	0.809** (0.000)
OPI	0.941** (0.000)	0.966** (0.000)	0.753** (0.000)	0.752** (0.000)	0.453** (0.000)	0.798** (0.000)
DMS			0.773** (0.000)	0.816** (0.000)	0.457** (0.000)	0.757** (0.000)
UMS					0.643** (0.000)	0.999** (0.000)

*Correlation significant at the 0.01 level (2-tailed).

**Correlation significant at the 0.05 level (2-tailed).

Numbers in parentheses are two-tailed significance levels.

†64 degrees of freedom.

‡22 degrees of freedom.

The null hypotheses of this study compare correlations (r). To test for the statistical significance of the differences in correlations given different sample sizes (n), the correlations were transformed to values of a standard normal distribution using formulas suggested by Kanji (1994), as follows:

$$Z_1 = \frac{1}{2} \log_e \frac{1+r_1}{1-r_1}, \quad (16)$$

$$\sigma_1 = \frac{1}{\sqrt{n_1 - 3}}, \quad (17)$$

$$Z = \frac{Z_1 - Z_2}{\sqrt{\sigma_1^2 + \sigma_2^2}}. \quad (18)$$

Thus, the statistical significance of a difference in correlations was assessed by noting where the Z -score difference (Equation 18) fell along the standard normal distribution.

Hypothesis 1 is rejected. The correlation between ATI and DMS is significantly higher than that between EPS and DMS in the service industry ($Z = 2.11, p = 0.018$, one tail) and in the manufacturing industries ($Z = 8.55, p = 0.000$, one tail). As argued, the difference may be explained by the variability in shares outstanding in the service industry ($M = 114.7, SD = 85.1$) and in the manufacturing industry ($M = 202.9, SD = 421.6$).

Hypothesis 2 is rejected. The correlation between OPI and DMS is higher than that between ATI and DMS in the service industry ($Z = 19.05, p = 0.000$, one tail) and in the manufacturing industries ($Z = 24.16, p = 0.000$, one tail). As argued, the difference may be explained by the variability in other income and expenses in the service industry ($M = -3,574.4, SD = 18,128.7$) and in the manufacturing industry ($M = -2,120.6, SD = 28,671.7$).

Hypothesis 3 is partially rejected. The correlation between ATI and UMS is insignificantly lower than the correlation between ATI and DMS in the service industry ($Z = 0.34, p = 0.368$, one tail), but the former correlation is significantly lower than the latter in the manufacturing industries ($Z = 7.95, p = 0.000$, one tail).

Hypothesis 4 is rejected. The correlation between OPI and UMS is significantly lower than the correlation between OPI and DMS in the service industry ($Z = 17.07, p = 0.000$, one tail) and in the manufacturing industries ($Z = 33.54, p = 0.000$, one tail).

Hypotheses 5 and 6 are both rejected. The correlation between ATI and x is significantly higher in manufacturing industries than in the service industry ($Z = 4.89, p = 0.000$, one tail), and so is the correlation between OPI and x ($Z = 4.23, p = 0.000$, one tail).

Hypothesis 7 is partially rejected. The correlation between ATI and x is not significantly lower than the correlation between ATI and DMS in the service industry ($Z = 1.32, p = 0.093$, one tail), even though the tendency is in the expected direction. Still, the former correlation is significantly lower than the latter in the manufacturing industries ($Z = 7.78, p = 0.000$, one tail).

Hypothesis 8 is rejected. The correlation between OPI and x is significantly lower than the correlation between OPI and DMS in the service industry ($Z = 20.09, p = 0.000$, one tail) and in the manufacturing industries ($Z = 32.31, p = 0.000$, one tail).

Except for the three insignificant correlations of EPS in the service industry and three moderate correlations ($0.30 < r < 0.50$) with respect to production experience in the service industry, all correlations are strong ($r \geq 0.5$). The insignificant correlations may be accounted for by the flaw of using EPS in the correlation model and the three moderate correlations may be accounted for by the relatively large component of production cost that is fixed in the service industry, all of which has been explained.

CONCLUSION

This study extends Faria and Wellington's (2004a) research. Contrary to their finding of generally moderate correlations between profitability and market share, this study finds strong correlations, a result consistent with Buzzel and Gale's (1987) seminal work. The difference in findings is apparently due to the greater competitiveness of the simulation used in this study, and the greater number of periods of its administration.

This study highlights the importance of measurement in studies of this kind. The strength of the correlation between profitability and market share depends greatly on how the two constructs are measured. Better measurements yield stronger correlations.

Finally, this study supports Buzzel and Gale's (1987) assertion that the effect of market share on firm profitability is stronger than the effect of production experience, but it also supports Henderson's (1984) argument that production experience is a complex variable of strategic importance. The issue comes down to understanding how variables interact, and not a choice of one or the other.

It is in understanding how variable interact that business gaming simulations can make a distinctive contribution to the understanding of strategic business processes. Faria and Wellington (2004a) justified their work as a contribution to the "validation of the use of business simulation games for teaching purposes" (p. 335). Although their work and this study certain accomplishes that objective, one might also observe that the use of business gaming simulations is pervasive, having extended to about 97.5 % of AACSBs schools by 1998 (Faria & Wellington, 2004b). At this level of acceptance, the case for the utility of business simulations has been made. Business gaming

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simulations merit study because they show the action and re-action of social forces in a controlled environment. They have become pervasive, which is why they should be better understood.

Caution is warranted in generalizing from the laboratory setting to the application setting, but caution also is warranted in generalizing from field studies conducted in the 1980s, 1990s, even yesterday, to the application setting of the present time. Both laboratory work and fieldwork seek to understand laws of nature that transcend space and time. Both have their merits and demerits. The use of both approaches for both teaching and research is well established in the natural sciences. The same may become true of the business-administration field in the years to come.

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