Pergamon

Journal of High Technology
Management Research 80 (2002) 1–21

THE JOURNAL
OF HIGH
TECHNOLOGY
MANAGEMENT
RESEARCH

The neural firm
Burns and Stalker in extenso

Foo Check-Teck*[,1], Lee Tuck-Suen[2]

MPE Centre for Engineering and Technology Management, Nanyang Technological University,
Nanyang Avenue, Singapore 63979, Singapore

Accepted 27 February 2002

Abstract

We theorize that organizing learning activities in high-technology firms differs from those in conventional manufacturing. Using controls, we found empirical support for our hypotheses, which are due to market turbulence. High-technology-driven firms had to face a rapidly changing, highly volatile environment with disruptive and destructive changes. Inspired by our findings, we suggest an extension to the Burns and Stalker's idea of the "organic" firm—a neural firm paradigm in interpreting people–technology interactions. For high-technology firms having to cope with market turbulence, we argue for "plasticity" in organizing. © 2002 Published by Elsevier Science Inc.

---

1. Introduction

The role of the environment in influencing corporate behavior continues to be of central interest among leading scholars and researchers (e.g., Bourgeosis, 1985; Grinyer, Ardekani, & Al-Bazzaz, 1980; Jauch & Kraft, 1986). This is despite the already extensive literature

---

* Corresponding author. Fax: +65-7921911.
E-mail address: mctfoo@ntu.edu.sg (F. Check-Teck).

[1] Foo Check-Teck, the main author, is currently an Associate Professor at the Nanyang Technological University, Singapore, and a Visiting Professor of Technology Strategy at the New York Institute of Technology, USA.

[2] Lee Tuck-Suen was a research student under the supervision of Foo Check-Teck at the School of Mechanical and Production Engineering, Nanyang Technological University, Singapore.

1047-8310/02/$ – see front matter © 2002 Published by Elsevier Science Inc.
PII: S1047-8310(02)00045-7

dealing with diverse perspectives on the environment and the firm (e.g., Child, 1972; Downey & Slocum, 1975; Duncan, 1973; Khandwalla, 1972; Lawrence & Lorsch, 1967; Leifer & Huber, 1977). The continuing onslaught of high technology in the new economy brings with it even more turbulent changes into the business environment of the 21st century.

Not surprisingly then, Burns and Stalker's landmark findings of the 1960s' *The Management of Innovation* remained relevant, if not enhanced. Their work continues to be integrated almost routinely into the many standard texts dealing with the management of organizations. How is this so? What did their research really tell us?

Burns and Stalker's research informed us about the influences of the environment on manufacturing firms. After extensive, detailed, and empirically grounded investigations, they established a dichotomy between firms that were structurally *mechanistic* and those that were *organic*. Firms, according to Burns and Stalkers, that operated within a rapidly changing environment (RCE) shared a common attribute—"organicness." In sharp contrast, firms within a stable, thus predictable, environment were described as organizationally mechanistic. It is this "organicness" attribute identified by Burns and Stalker that inspires us in our own empirical research into the impact of the environment on firms.

Since their classic work, the global manufacturing environment had more than evolved (e.g., Terreberry, 1968), it had undergone dramatic transformation, with its momentum of change remaining unabated. In contrast to the manufacturing environment of Burns and Stalker's time, ours is subjected to far more rapid changes, thus producing unpredictable, complex, and even turbulent environment. The on-rushing streams of new technology had accelerated the pace of change. The greatest and most immediate impact is on firms operating in the context of high technology, such as those within the electronics industry. The environment had evolved to be far more ruthless and competitive. Such an environment could account, in part, for the unprecedented proliferation of new management concepts, methods, and techniques.

The avalanche of materials is coming out mainly from the US. This is reasonably expected as relatively more US firms are operating at the cutting edge of technological innovations than others are. The US, at least for now, dominates the world in the software industry by producing technology that drives changes in the landscape of manufacturing across many diverse industries. In addition, there are many new developments in consumer electronics (e.g., newer, smart materials, ever tinier and slimmer chips, etc.) that demand higher sophistication and greater flexibility in manufacturing capability. This results in an increase requirement for responsiveness and agility in manufacturing firms, driving up the level of competitiveness in the industries.

Such rapid gushes of new technologies had reconfigured the competitive landscape. The stark choice often confronting firms in such an environment is either to cope or be left out. The environment is often perceived as being subjected to sharp discontinuities. The disjointed streams of technologies are not only disruptive, but are also often proven destructive to established firms that are unable to keep up with the momentum of change. Such disruptive changes in technology often deepen the sense of inadequacy among managers, particularly in the high-technology sector of manufacturing. Thus, there is that constant search by managers for new strategies, concepts, ideas, techniques, tools, methods, and understandings in order to be effective in coping with change. The intensity and rapid rates of technology change are likely to be sustained into the future. Not uncommonly, firms in the electronics industry are facing environmental changes that are characteristically rapid, sudden, abrupt, and severe.

For firms competing in the high-technology segment, the pressures on management are likely to become ever more intense. There is unrelenting pressure on management to cope with the tremendous influx of new technologies, as well as obsolescence of the old. The social costs in trying to cope with the turbulence from such an environment (e.g., stress) has yet to be truly and fully appreciated. However, it is precisely such a scenario that provides us, as researchers of organization–environment interactions, with an exciting background to conduct our research.

Our overarching concern here is on the impact of the environment on organizing in firms. In other words, how do organizations respond in trying to cope with a RCE of severity likening to that faced by high-technology firms? Unlike Burns and Stalker, we are able to, through our large-scale database built up over several years since 1988, capture through quantifiable means differences in organizing for learning between firms in the electronics industry and those operating inside conventional manufacturing. In general, firms in conventional manufacturing operate in a *more* stable and predictable environment, as compared to firms in the electronics industry.

Our study focused mainly on the core value-adding elements: *production workers* and the *machinery* deployed in the manufacturing processes. In production economics, the critical inputs remained to be that of labor (i.e., workers) and capital (technology/machinery that improve labor efficiency). Profit is generated from the interactions between labor and capital, i.e., worker–technology interactions. The productive capacity that results from such interactions is intriguing. Economists routinely reflect on this phenomenon via the proxy measure commonly referred to as productivity—being a simple ratio between output and input. Yet, we are surprised that so few studies had been undertaken to investigate such interactions on empirical ground. Considering that we are in the midst of rapid technological changes, the interactions between workers (e.g., their learning) and technology (e.g., its implementation) ought to be of central importance.

We will take a brief historical perspective of the relationship between labor and capital (machinery). With the emergence of the “factory” at the dawn of the industrial age, there arose a global trend in market economy: machinery encroaching more and more into the arena of work performed by workers. We could interpret the rationality of this trend using the idea of efficiency in the production floor. Considering that efficiency leads to more profits, thus enhancing corporate value (e.g., in stock prices), production efficiency (e.g., through just-in-time processes) thus remains the key meaningful production floor measure of corporate performance. It is not surprising then that machinery, being more efficient, effective, and always *mute*—in contrast to workers who are inclined to collective voice through union intervention—as a means of production, is replacing more and more of labor. To put our argument bluntly, machinery is no longer supplementary to the work of labor. Since the turn of the British industrial revolution, machinery in the production lines had become direct substitutes for labor. Labor, especially the production workers, had instead become supplementary to machinery in the production process. They fulfill what the machines are, *for the moment*, unable to do in a less *costly* manner (new machinery are a lot more expensive than a pair of hands), although less effectively.

For firms to cope with technology change, we argue that there must be learning by workers, specifically production workers, as per our present study. Firms need to rely on production workers to achieve smooth and on-time implementation of machinery that is embedded with new technology. Unless he is constantly "en-skilled" through training and learning, the average capability of the production worker is likely to remain stagnant. The untrained production worker is likely to encounter severe difficulties in fulfilling his task. Indeed, a production worker's level of skill, unless upgraded, is in *relative* decline, given the rapid increase in complexity of new technology-oriented machinery. In relating the capability of a production worker to the execution of a new task, such as operating new computer-aided machinery, we realize that unless en-skilled, the same worker runs the risk of being replaced by another more highly skilled person. This brings us to a related phenomenon from which our research takes its bearing—the transformation of work.

The once "hard" machinery that the production workers had to handle in order to produce higher-quality goods more efficiently is becoming "soft," and it is becoming ever "softer." The machinery used for production within the electronics industry have especially evolved to become ever more "intelligent." Production workers caught in such fast-changing environment, such as that faced by the electronics industry, may already be finding the production task too difficult to cope up with. This is so, even with *piece-meal* training—training implemented as and when required—or *in-step* with the implementation of new technology. A corporate setting that fosters learning has become necessary. A yearning for deeper knowledge and understanding, and the ability to grasp the underlying theory of the production process beyond button pushing is now required of workers. In other words, training must engender a habit of learning independent of, though related to, the immediate task of operating a particular machinery.

In the near future, problems of learning are likely to be accentuated as later generations of production machinery become ever more complex, modular, and intelligent. It is even likely that some of these machines may begin to "learn" on the production floor, diminishing the role of workers. One could anticipate the increasing pressure on the production workers, not only to cope, but also to *compete* head-on, with machinery. In order to be assured of their jobs—often their only means of livelihood—production workers would have to be accustomed to continuous learning. This is especially so for workers working in firms where the competitive edge is dependent on responsiveness to changing technology. The management of technology changes will be quite a challenge for those responsible for it. All these contribute to our interest in investigating the impact of rapid and intense technology change on firms operating in the electronics industry—the industry most severely affected by technology transformation today.

2. Framework of hypotheses

We developed a simple framework (see Fig. 1) to guide our empirical investigation into the possible impact of a RCE on organizing learning activities inside high-technology firms

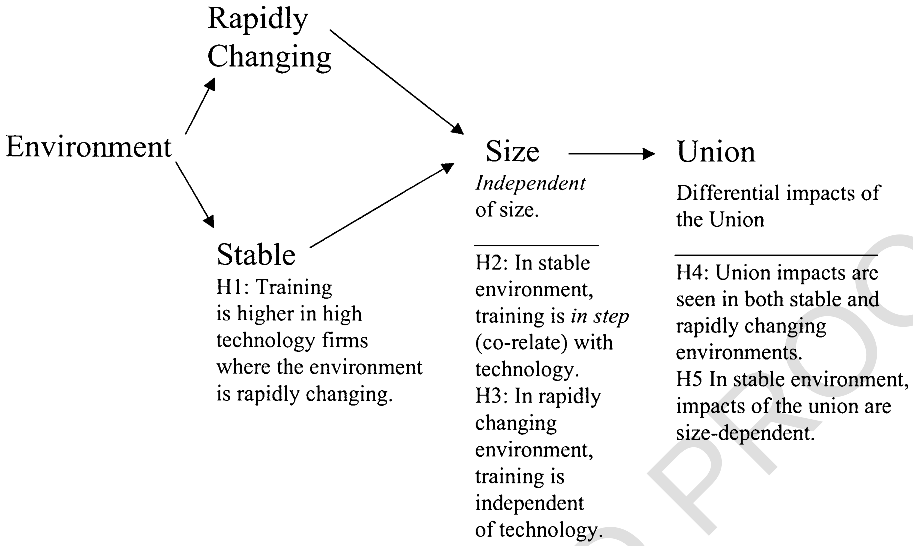

Rapidly Changing
Environment
Stable
H1: Training is higher in high technology firms where the environment is rapidly changing.
Size
Independent of size.
H2: In stable environment, training is in step (co-relate) with technology.
H3: In rapidly changing environment, training is independent of technology.
Union
Differential impacts of the Union
H4: Union impacts are seen in both stable and rapidly changing environments.
H5 In stable environment, impacts of the union are size-dependent.

Fig. 1. Framework of hypotheses related to labor technology and worker training.

(Ford & Slocum, 1977; Khandwalla, 1972; Hitt, Ireland, & Stader, 1982). Our motivation is to gather empirical support from Asia, that there are perceivable structural differences between the manufacturing firms operating within a *stable* environment and those operating within a *rapidly changing* and often *highly volatile* environment. Dill (1958) had long argued that environment influences how a firm is organized in terms of its autonomy. Here, we are focusing on the impacts of rapid change in technology as environment on technology-based organizations (i.e., manufacturing firms) in organizing for worker training. This is our rationale for isolating microelectronics firms for analysis within our manufacturing sample.

Singapore, as a national site, is an appropriate choice to ground the investigation as it is a highly popular production base for many leading electronics firms such as Seagate, Motorola, AT&T (now Lucent Technology), among many others. We focus mainly on perceptible difference in organizing learning activities, skills building, and knowledge gathering (or cumulatively “training”) among production workers, between firms operating in contrasting environment: stable versus rapidly changing.

Our research design involved the use of controls during the testing of our hypotheses. Prior to statistical analyses, we instituted controls to the sample responses collected. This is consistent with our earlier analytical design (Foo, 1990b). First, we selected only firms within the manufacturing sector for analysis. Then, we instituted controls by isolating the perceptual responses of electronics firms (high-technology, rapidly changing, and highly volatile environment) from those from conventional manufacturing (relatively stable environment). This is to facilitate us in validating our hypothesis that in environment where there are inflows of rapidly changing, fast-moving new technology, the level of training in such firms tends to be higher than that in a relatively stable environment. This leads us to our first hypothesis:

> *Hypothesis 1:* Training is higher in high-technology firms where the environment is rapidly changing.

We argue that under conditions of stability and predictability, firms tend to experience a more lax environment, hence, being able to schedule training to be timely and in-step with changes made to production technology. Thus, we expect the implementation of technology for labor efficiency to be significantly (significant at the .05 level) correlated with worker training for firms operating in a stable environment. In other words, training is being *stepped up* when there is increased use of labor technology for productivity gains. Reframing our intuitive argument as a hypothesis, we may state the following:

> *Hypothesis 2:* In a stable environment, training is in-step (correlated) with technology change.

However, in an environment where rapid change is a consequence of changing new technology, we argue that firms have to sustain training independent of specific implementation of new technology (embedded in new production machinery). In other words, training is less in-step with the influx of technology change. Thus, we have the third hypothesis as follows:

> *Hypothesis 3:* In a RCE, training is independent of technology.

Next, we exercised control for union presence. In so doing, we want to be able to refine our theory on the possible roles of collective voice through unionization, building on earlier research (Foo, 1991a, 1991b). The impact of union presence is an exciting variable for us to investigate, especially in the context of Singapore where the national body for trade unions—the National Trade Union Council (NTUC)—is constantly promoting the training and upgrading of workers' skills. Therefore, we expect some measurable impact of union presence on workers' training, especially when labor-saving technology is being implemented.

We will proceed to theorize on possible influences of union presence. If the union emphasizes training as a *general* strategy for improving the *all-round* skills of workers and their continual development—as is the strategy adopted in the electronics industry—then, union interventions are independent of technology change and implementation. Hence, we do not expect any correlation between labor technology use and production worker training that is statistically significant (at the .05 significance level) with union presence. Conversely, it is also possible to argue that where the amount of training is inadequate, and where workers have to learn to operate machinery embedded with new technology, union would intervene to influence training. If largely so, such interventions would be reflected in statistically significant correlation between labor technology use and production worker training. This could happen within electronics firms, given that union would be concerned (viewing that union members do pay dues) that its workers survive the fiercely competitive environment.

The opposite situation takes place when there is a lack of collective voice. In the absence of the union, firms may budget for training when technology is being implemented out of consideration for productivity gain. Such training yields immediate and tangible economic returns when production workers are able to operate the new machinery. If so, we expect a significant pattern of correlation between implementation of labor technology and production workers' training. Training is thus organized only as and when firms require implementation of new technology. These arguments lead us to formulate the following hypothesis:

Hypothesis 4: Union impact is seen in both stable environment and RCE.

Extending on Hypothesis 4, we further theorize on the possible influence of firm size (Foo, 1990a, 1995). In theory, larger firms are more bureaucratic, structured, and have a greater slack in resources than smaller ones. As such, size may act as an effective buffer, enabling larger firm to be better able to respond in tandem with changes in technology. However, in rapidly changing, intensely competitive, and high-technology firms (as in the case of electronics firms), size could hardly be a buffer. Although firm size renders economy of scale in general, efficiency gain may be traded off when there are abrupt changes in technology. Since the much larger, high-technology firms had to be as rapidly responsive as the smaller ones in order to survive, their workers would be subjected to even greater pressure. If their workforce fails to assimilate the new technology quickly, such large firms may find themselves failing in their business. In other words, unlike firms in conventional manufacturing where the environment is stable and predictable, firm size is unlikely to result in any statistically significant correlation among the electronics firms.

In general, the management of the smaller firms is likely to require more agility, cost consciousness, and adaptability than the larger ones. In this regard, smaller manufacturing firms may more readily subscribe to providing training for their workers when new technology is implemented. We argue that this is more likely when the environment is stable, predictable, and where union is absent. This is because when union is present (as we theorized earlier), the union may exert pressure on the small manufacturing firms to emphasize all-round training, independent of technology implementation. Without union intervention, there is likely to be tighter coordination between when technology is implemented and when related training is provided for the workers.

Size is likely to matter less where the environment changes rapidly. As we have argued, firms—whether small or large—in a RCE may have to sustain training in order to cultivate a habit of learning in the work force. This being the case, we do not expect any statistically significant correlation when the control for firm size is applied. Following the arguments forwarded, we formulate yet another hypothesis:

Hypothesis 5: In a stable environment, the impact of the union is size dependent.

Section 3 will provide highlights of the empirical procedure adopted and the database of responses collected.

3. Empirical procedures and database

3.1. Controls

We instituted controls in order to facilitate the empirical testing of Hypotheses 1–5. The controls are clearly mapped out in Fig. 2. For example, firm "a" refers to those within the manufacturing industry that are of high technology, large firm size and unionized context. In contrast, Firm "b" refers to those within the manufacturing industry, but not of high technology (outside box "high technology"), though of unionized and small firm size (outside box "large") context.

To control for environmental volatility, we ran through the individual responses from our sample of manufacturing firms (having removed firms from the "services" sector) to identify those from the electronics industry. The respondents had been asked to reveal their industry in the survey instrument. In so doing, we avoided the controversies evident in the literature concerning the measurement of environmental uncertainty. Take, for example, the debate between quantitative versus qualitative, perceptual versus objective (Downey & Ireland, 1979; Downey & Slocum, 1975); on the complexity of state, effect, and response concerning uncertainty (Milliken, 1987); and on the different dimensions depicting the environment (Tung, 1979). By identifying the electronics firms from the larger manufacturing sample, we are implicitly assuming that the major source of volatility in the smaller sample of electronics firms is technological.

3.2. Database

The very large-scale sample (N=1621) used in our analysis is an extension to an earlier 1988 database of perceptual responses concerning corporate productivity improvement practices (Foo, 1990b). That 1988 database (N=70) was built up by the first author himself, who both

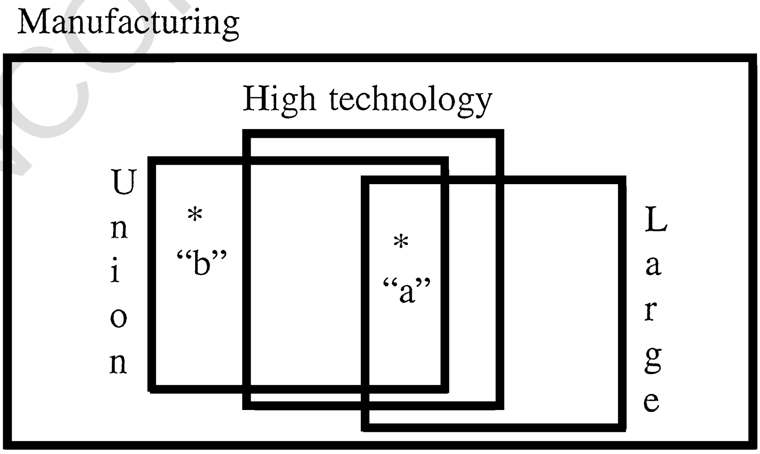


Fig. 2. Framing the analysis by use of controls.

Table 1
Sample characteristics of the entire sample

	Frequency (*n*=1621)	%
Manufacturing	657	40.5
Services	892	55.0
Government	72	4.5

designed and administered the survey instrument. He did that in the capacity as an instructor of a productivity improvement program held under the aegis of the National Productivity Board (NPB) of Singapore (now known as the Productivity Standards Board, PSB).

Such a massive database capturing the perceptions of corporate productivity practices is rarely available, especially from firms in Asia. This was only possible through the collaborative efforts of other instructors who assisted in the administration of the same instrument to a wide array of participants over a period. The main and first author continued to use the instrument to gather data from the workshops that he conducted himself from 1988 to 1993. The second author, as a research student, then helped to extend the database from 1994 to 1995 by coordinating the data collection effort of the other instructors at the National Productivity Board.

The sample characteristics (40.5% manufacturing, 55% services, and 4.5% government) of the extended database (which we shall name the Center for Engineering and Technology Management, CETM, database) is given in Table 1. From this extended CETM database, we extracted our manufacturing subsample (*n*=496). These are firms who clearly described the nature of their business as "manufacturing" in the instrument. Details of this subsample are given in Table 2, where 60.9% (*n*=302) are classified by us as operating within a stable

Table 2
Characteristics of the manufacturing sample of firms

	Frequency (*n*=496)	%
Market environment		
Stable	302	60.9
Rapidly changing	194	39.1
Firm size		
Small	153	30.8
Large	343	69.2
Union presence		
No	289	58.5
Yes	205	41.5
Respondent level		
Top management	23	6.7
Middle management	220	44.5
Supervisory	144	29.1
Nonexecutive	97	19.6

environment (manufacturing firms other than those in electronics) and 39.1% (n=194) as operating within a RCE (firms in electronics sector).

For analytical purposes, we split the manufacturing firms into an "all other industries" subsample (n=302)—typified as operating in a "stable" environment, and an "electronics" subsample (n=194)—typified as operating in "rapidly changing" environment. After the split, we were surprised at some striking similarities between the sample characteristics of the two subsamples. They are as follows.

First, there is a similarity in terms of distribution of responses according to organizational hierarchy. Top management comprised of 7.6% for the sample of firms from all other industries, compared to 5.2% for the sample of firms from electronics.

Similarities are also observed across other levels: middle management, 46.2% versus 42%; supervisory 28.2% versus 30.6%; and nonexecutive 17.9% versus 22.3%.

Second, there is a similarity in terms of the proportion of firms with union presence. It is 43% in the all other industries sample and 39.2% for the electronics sample.

Third, there is a similarity in firm size distribution, even after having applied the difference in criteria for dichotomizing the sample into *small* versus *large* category according to the nature of the industry. Small firms comprised of 28.5% in the all other industries sample and 34.5% in the electronics sample. We had scaled <500 employees as small for electronics firms but kept to <100 for manufacturing firms outside of electronics (this being consistent with Singapore's industrial average) (Tables 3 and 4).

The Likert five-point scale is used in the instrument to reflect the responses for each survey item: 1=*none*, 2=*little*, 3=*some*, 4=*large*, and 5=*very large*. The two groups of survey items relevant in this paper are the perceptual measures on the extent to which (i) labor-saving technology and (ii) training and education for production worker are emphasized in improving productivity. A brief description is given in an earlier paper of this journal (Foo, 1997). In addition, for consistency with earlier results, we keep to correlation analysis.

Table 3
Characteristics of firms from other manufacturing industries

	Frequency (n=302)	%
Firm size		
Small	86	28.5
Large	216	71.5
Union presence		
No	171	57.0
Yes	129	43.0
Respondent level		
Top management	23	7.6
Middle management	139	46.2
Supervisory	85	28.2
Nonexecutive	54	17.9

Small firm: 100 or less employees. Large firm: >100 employees.

Table 4
Characteristics of first from microelectronics industry

	Frequency (n=194)	%
Firm size		
Small	67	34.5
Large	127	65.5
Union presence		
No	118	60.8
Yes	76	39.2
Respondent level		
Top management	10	5.2
Middle management	81	42.0
Supervisory	59	30.6
Nonexecutive	43	22.3

Small firm: 500 or less employees. Large firm: >500 employees.

Section 4 will evaluate the hypotheses established in the light of the results from this large-scale database of perceptions on corporate productivity practices.

4. Results

First, we discuss the implementation of labor-saving technology (Table 5). On the whole, it is clear that emphasis on labor-saving technology implementation is *higher* for firms operating within a RCE. This is easily explained by the intense competition faced by firms in the electronics industry. One strategy to survive both the rapid rate of change caused by new technology, and the intense competition in the industry, is to be efficient, effective, and timely in implementing new technology (see earlier discussion).

Table 5
Means on labor technology use

	Change	
Sample	Stable environment	RCE
Small companies	n=85, 3.26	n=65, 3.42
Large companies	n=214, 3.42	n=127, 3.68
Nonunion companies	n=168, 3.26	n=115, 3.57
Unionised companies	n=129, 3.50	n=74, 3.62
Small nonunion companies	n=64, 3.02	n=49, 3.39
Small unionised companies	n=20, 3.95	n=16, 3.50
Large nonunion companies	n=104, 3.40	n=66, 3.70
Large unionised companies	n=109, 3.42	n=58, 3.66

n=sample size.

The only exception, and therefore intriguing, is the small but *unionized* firms operating in a RCE. The emphasis (3.50) is lower than similarly *controlled* firms operating in a stable environment (SE; 3.95). The result suggests significant influences of the union inside the smaller electronics firms. One other possibility, of course, though remote, is that the result is the outcome of chance.

A persuasive argumentative angle would be to see the union as a restraining force. In other words, the union may curtail management in their aggressive implementation of new technology, especially that of the variety that ruthlessly substitutes workers. Another more likely possibility—more so for firms originating from the US where unionism is antagonistic rather than those from Germany or Japan where unionism is cooperative—managers may view the presence of union as threatening to their independence.

Consequently, managers in these firms could deliberately *underinvest* in technology, resulting in these perceptions.

With the above as background, we turn to our first hypothesis (see Hypothesis 1).

Looking at simple statistical means on production workers training, we find that across the various controlled samples of RCE firms, they are observed to be consistently higher (Table 6). The result suggests that learning through "some" (>3.00) extent of training is essential for firms operating in a RCE. As we had argued earlier, production workers in electronics firms have to learn in order to cope with the continuous influx of new technology. This is observed as well in the case of the small, unionized, electronics firms, where training is perceived to be considerably higher (3.59 vs. 2.30) than those of the small, unionized, conventional manufacturing firms. This is despite our earlier surprising result, where we find the implementation of technology in the small, unionized electronics firms to be lower (i.e., 3.95 vs. 3.50). Clearly, without the production workers mastering new skills through training, high volume production and quick turnaround times are unlikely to be realized. This is to be expected, given the fact that over the last decade, we had seen some of the most rapid, sudden, and sustained technological changes within the electronics industry.

We turn to the next hypothesis (see Hypothesis 2).

The data analysis provides a *picture* consistent with our hypothesis. In a stable and predictable manufacturing environment, the learning of production workers via training is

Table 6 t6.1
Means on production workers' training t6.2

	Change		
Sample	Stable environment	RCE	t6.4
Small companies	n=82, 2.52	n=65, 3.18	t6.5
Large companies	n=213, 3.00	n=126, 3.39	t6.6
Nonunion companies	n=166, 2.86	n=116, 3.28	t6.7
Unionised companies	n=128, 2.86	n=76, 3.38	t6.8
Small nonunion companies	n=62, 2.60	n=49, 3.04	t6.9
Small unionised companies	n=20, 2.30	n=17, 3.59	t6.10
Large nonunion companies	n=104, 3.02	n=67, 3.45	t6.11
Large unionised companies	n=108, 2.96	n=59, 3.32	t6.12

n=sample size. t6.13

achieved in-step with the implementation of labor technology for productivity improvement. Such a tendency, however, appears to be independent of firm size (see Table 7) [small companies (*n*=82), .3843 at the .001 level of significance; large companies (*n*=212), .2996 at the .001 level of significance].

The idea of environmental influence is central to this paper. We argue that a stable and predictable environment serves as *enabling conditions* to facilitate firms in organizing training, learning, and skill-building activities of production workers in an in-step manner with technology use. Environmental predictability enables firms to better relate training emphasis to technology implementation. In such a context, manufacturing firms implement learning largely in tandem with technology change (Boulton, Lindsay, Franidin, & Rue, 1982).

Next, we turn to our third hypothesis (see Hypothesis 3).

The data provides support for Hypothesis 3. We find that in the contrasting environment of rapid changes, there is an absence of any such correlation among high-technology firms. Clearly, one core competitive edge for firms in the electronics industry is to be "strong" in implementing high technology. Management in electronics firms, like their counterparts in conventional manufacturing, has to emphasize training when implementing technology: Production workers still need to acquire new skills in order to operate new machinery embedded with new technology. The following provides a few perspectives with regards to the lack of correlation observed.

One explanation may lie in the fact that production workers within the electronics industry are already highly skilled. However, such is unlikely the case in Singapore. The electronics industry absorbs labor inputs from essentially the same pool of workers. These production workers are unlikely to be better educated than the others. Despite the lack of differential in education, competitive pressures, however, require workers in electronics firms to be quicker in adapting and faster in learning. We opine that the explanations for the lack of correlation are likely to lie elsewhere.

Another more plausible explanation is that such in-step and technology-dependent implementation of training alone is inadequate for production workers to become effective

Table 7
Labor technology and production worker training correlations

	Change	
Sample	Stable environment	RCE
Small companies	0.3843*** (*n*=82)	0.1586 (*n*=64)
Large companies	0.2996*** (*n*=212)	0.0706 (*n*=123)
Nonunion companies	0.416*** (*n*=165)	0.0314 (*n*=113)
Unionized companies	0.2157* (*n*=128)	0.2300* (*n*=74)
Small nonunionized companies	0.4882*** (*n*=62)	0.0731 (*n*=48)
Small unionized companies	0.2399 (*n*=20)	0.3148 (*n*=16)
Large nonunionized companies	0.3477** (*n*=103)	−0.0565 (*n*=65)
Large unionized companies	0.2492** (*n*=108)	0.2049 (*n*=58)

* Statistical significance: *P*=.05.

** Statistical significance: *P*=.01.

*** Statistical significance: *P*=.001.

in coping with the violent changes in the technological environment (Koberg, Sarason, & Rosse, 1996). Failures by electronics firms to cope effectively with rapidly changing technology environment often imply an impending "death" (Nicholls-Nixon, 1995). Or less drastically perhaps, such failures of production workers to learn and implement new technology quickly often lead to an underachievement of strategic goals, poorer economic performance, or both (Bourgeosis, 1985; Grinyer et al., 1980).

The contrast in the pattern of correlation is intriguing. Clearly, firms in the highly volatile electronics industry are emphasizing training and learning of skills among production workers *independently* of new technology implementation. Yet, organizing training and learning activities for production workers inside electronics firms ought to be a major structural adaptation to survive environmental volatility (Ardekani, 1986). This is reflected in part in the level of training being emphasized (as discussed earlier): The training of production workers in electronics firms is perceptually higher when compared to those in conventional manufacturing.

We suggest the following additional insights:

1. We argue that for electronics firms to surmount difficult and volatile environment, the training activities of the production workers have to be deeply integrated and ingrained into the corporate culture.
2. Another way of putting it is that learning by the production workers has to be sustained such that it becomes integral to their work life, and in some cases, part of their daily routine.
3. Learning new technology must necessarily become part of the mindset of the production workers, in order for an electronics firm to outperform its competitors.

From these correlation analyses, we observe that the training and learning activities of production workers in the electronics firms are largely *independent* of technology implementation, as we had anticipated. Learning, adaptable, and flexible production workers are essential if electronics firms are to continuously absorb the influx of technology changes taking place.

There could, however, be yet another plausible explanation. The influx of new technology within the electronics industry is highly random and unpredictable despite its increasing frequency, or even rapidity. As such, systematic and technology dependent training are not reflected as statistically significant correlation. In other words, no discernible pattern in correlation is possible in such highly volatile circumstances.

Further, with our controls on the sample being limited to only the high-technology electronics firms, it is not possible to probe into intermediate technology situations—a potential avenue for extending our current research. However, it remains attractive for us to hypothesize a pattern of decreasing technology-training correlates in an increasingly uncertain environment, as we believe is validated in a high-technology context (Bourgeosis, 1978).

Another possibility for the lack of statistically significant correlation may also be due to the situation where both the levels of training and technology emphasis are already high in the electronics sample. The more interesting results, however, are to be found in the exceptions. The *lack* of such statistically significant relationships suggests that the underlying phenomenon may be more complex than apparent. This leads us to the next hypothesis where we probe for deeper insights via the institution of control for union presence (see Hypothesis 4).

Our result bears out to be consistent with the hypothesis. Interestingly, we found that the correlation emerging out of the unionized electronics firms to be statistically significant (.2300, *n*=74, .05 level of significance), whereas that emerging out of the *nonunionized* electronics firms to lack statistical significance. We are inclined to argue that union presence ensures *some*, though not too functional, coordination between training for workers and technology implementation. In sharp contrast, statistically significant correlation (.416, *n*=165, .001 level of significance) is found in nonunionized manufacturing firms operating in a stable environment.

Clearly, in the absence of the union, the training of production workers is strongly and tightly coordinated as to be in-step with technology implementation for firms within a stable environment. With union presence, the correlation between training and technology is still statistically significant, but far weaker (.2157, *n*=128, .05 level of significance). In other words, union presence has a decoupling effect on the training and technology relationship.

Now, we turn to our firm size-related hypothesis (see Hypothesis 5).

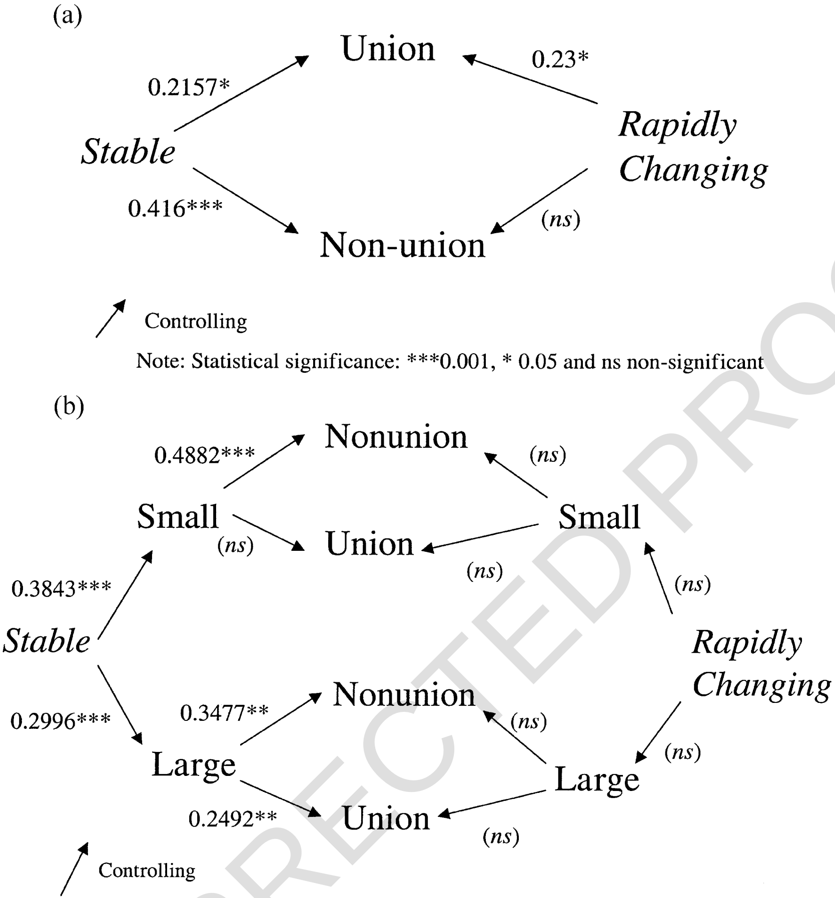
Arguably, it is easier for smaller firms to coordinate and synchronize training to technology implementation. This is clearly demonstrated in our result, where in nonunionized context, the correlation for the large companies is statistically less significant (.3477, *n*=103, .01 level of significance) than that for the small companies (.4882, *n*=62, .001 level of significance). In the unionized context, the result is even more sharply contrasting. The correlation of training and technology implementation for the small, unionized companies is not statistically significant at all. In the large, unionized companies, the correlation (.2492, *n*=108, .01 level of significance) is moderately high and statistically significant. The result therefore supports our intuitions that union impact is size dependent within the context of a stable and predictable environment.

In Section 5, we will map out our findings in order to extend on the conceptualizations suggested by Burns and Stalker in the 1960s.

5. Burns and Stalker in extenso

To generalize the detailed results from the empirical database, we provide an abstracted presentation in Fig. 3B.

Clearly (see Fig. 3B), there is an interestingly sharp contrast in the pattern of correlation between firms operating in a stable, predictable environment, and those in a rapidly changing one. One could remark in passing that organizing learning activities by firms for production workers in a stable manufacturing environment is largely independent of firm size (i.e., small vs. large) and is tightly coordinated and in-step with the implementation of technology. To borrow from Burns and Stalker's terminology, training takes place more mechanistically: this happens, then that occurs.


(a)
Union
0.2157*
0.23*
Stable
Rapidly Changing
0.416***
(ns)
Non-union
Controlling
(b)
Nonunion
0.4882***
(ns)
Small
Small
(ns)
Union
(ns)
0.3843***
(ns)
Stable
Rapidly Changing
Nonunion
0.2996***
0.3477**
(ns)
(ns)
Large
Large
0.2492**
Union
(ns)
Controlling

Note: Statistical significance: ***0.001, * 0.05 and ns non-significant

Note: Statistical significance ***0.001, **0.01 and ns non-significant

Fig. 3. (a) Pattern of labor technology and production worker training correlations. (b) Contrasting pattern in labor technology and production worker training correlations.

At the other end of the volatility spectrum, training within firms in a RCE (as in the electronics industry), though more highly sustained and emphasized (as it is perceived to be at a higher level), appears to be independent of technology implementation. It is common knowledge that in the electronics industry, the infusion rate of new technology is very rapid, sudden, and takes place in an unpredictable influx. The empirical results provide for us a basis to extend on the mechanistic–organic schema originated by Burns and Stalker in the 1960s.

We wish to extend from Burns and Stalker's idea of the organic to the *neural* (see Fig. 4). We believe that a new paradigm has to be construed to facilitate technology firms, especially the high-technology ones, to better manage the learning processes of production workers. Additionally, since learning takes place predominantly in the workers' minds, neuronal studies on the processes of our human brain ought to be sources of inspiration. In other

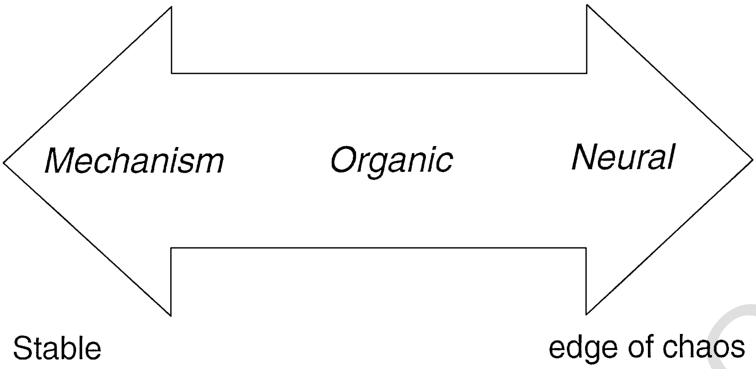


Fig. 4. Burns and Stalker in extenso.

words, our electronics firms may be required to be not only organic, but also neural (to be discussed later). Production workers are increasingly expected to learn on their own (e.g., via self-learning on the Internet) in order to cope with swift and unexpected changes in new technology. Firms at the cutting edge of technology change are under intense pressure to adapt quickly, or risk becoming part of "history"—drawing the analogy from Darwin's "survival of the fittest."

To conclude, we invoke a new paradigm—the neural firm.

6. Neural firm: towards a new paradigm

Earlier literature had already recognized the deterministic roles of environment in shaping the internal organization of firms (Dill, 1958). In a volatile, rapidly changing, and high-technology environment, firms must nurture production workers to be capable of unlearning old and obsolete methods of working to quickly learn new technology in order to cope with current changes (Cohen & Levinthal, 1990). Within the fast-moving electronics industry, technological changes are sudden, intrusive, often pervasive, and overwhelming.

There is, however, a paradoxical lesson on organizing—the more intense the rate of change, the greater the need for *less* complexity in organizing (Galbraith, 1973). It brings us beyond the deployment of organization devices such as differentiation and integration (Lawrence & Lorsch, 1967). Organizations that are ordinarily rational, *natural*, and open (Scott, 1981) had to additionally become neural in order to cope with such rapid changes in the environment (Fig. 5) (Jauch & Kraft, 1986).

We derived the model of the neural firm from McCulloch and Pitts' biologic neuron. The basic idea is that people in firms that are constantly under intense environmental pressure cope with changes through *fast* learning. In applying neural analogy, workers have to behave like "neurons" in the brain and display high self-organizing ability.

Thus, when existing machinery becomes useless through rapid obsolescence—now *months* rather than years—workers must quickly *interconnect* themselves to newer technology in order for the firms to survive. Useless machinery is akin to a damaged part of the brain.

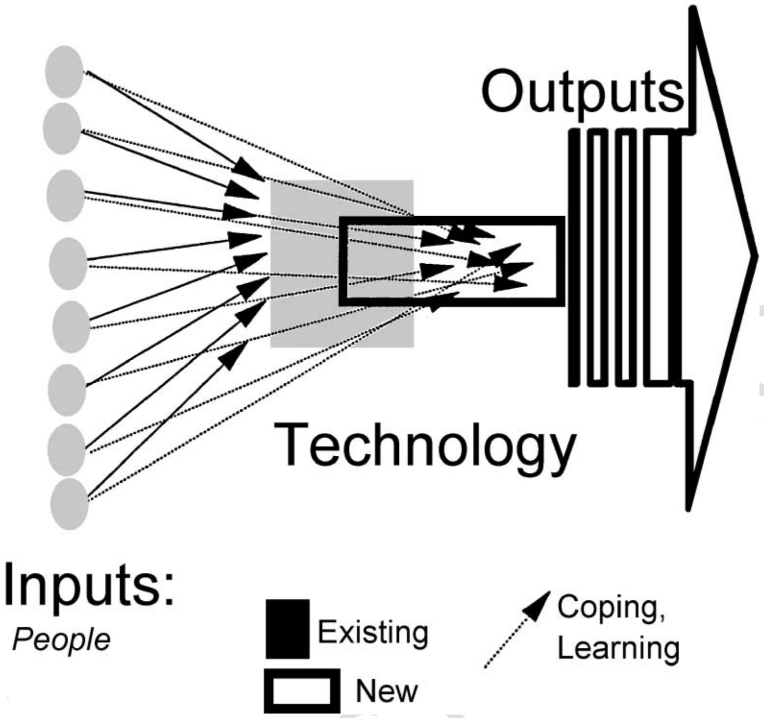


Fig. 5. Neural firm.

Workers need to learn to act like neurons in responding to such obsolescence. Supposing the eye is hurt, the cells inside the brain will quickly reorganize themselves to minimize any negative impact. These cells will strive to ensure that other sensing functions are enhanced to compensate for such a loss.

As highlighted earlier, machines, too, are becoming more *human*. They are acquiring intelligence through breakthroughs in development of neural technology. As the survival of firms in a RCE rely increasingly on the speed at which workers "cointegrate" with new technology, effective learning will become a necessary criteria. In other words (as the empirical result suggests), rather than seeing training as an immediate response to technology change, such firms need to view training as analogous to "glial cells." These glial cells are necessary for sustaining and supporting the activities of the neurons (Sylwester, 1995). Similarly, a glial-like presence of a learning culture, brought about through training and education of the production worker, will determine whether production workers are quick enough to cope with new technology [see Fig. 6—a juxtaposition of the firm (brain) and worker–technology synergy (neurons)].

Such "synapses" (worker–technology, as well as worker–worker) are more likely if training is sustained independent of technology change. Continuous learning fosters efficient synapses of interactions between the worker and machinery. Such *synapses* promote growth in the reservoir of tacit knowledge (Winch, 1999) that are stored as memory (being the

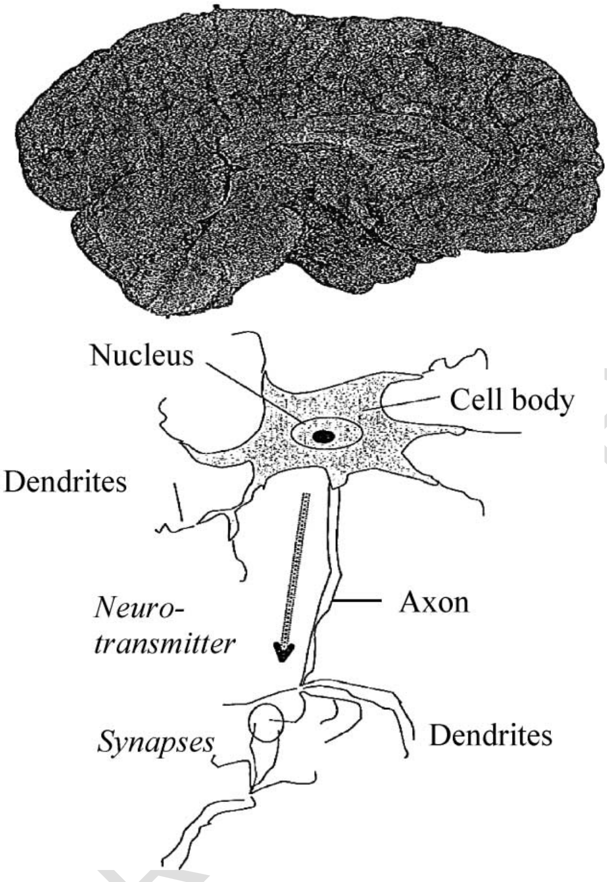


Fig. 6. Brain of the firm.

patterning of synapses). This is the reason why we argued for a lack of statistically significant correlation between training and technology implementation in the sample of electronics firms. We are indebted to Sherrington (1897) who first gave neurological literature the term ‘‘synapse’’ and argued that ‘‘synapse’’ is strategic in learning. Sherrington made an interesting statement concerning nerve cells in the brain:

> . . . the nerve cells directs its pent-up energy towards amplifying its connections with its fellows, in response to the events which stir it up. Hence, it is capable of an education unknown to other tissues . . . (p. 1117).

Applying the analogy of the brain to the firms, we may argue that a high-technology firm’s success, in an environment so taxed and vexed by rapidly changing production technology, is dependent on her ‘‘plasticity’’—a concept familiar to neurologists and psychologists. Plasticity implies an inherent quality nurtured within firms that enables them to sustain a culture of learning, in order to function *neurally* like the brain. This is in relation to the brain’s self-organizing qualities.

A "plastic" firm is more than just being characteristically flexible. Production workers operating in a culture of high training and learning are able to self-learn. Like nerve cells in the brain, they possess the skills to "synapse" themselves onto new and emerging technology. This ensures the continual survival of the firms that are "injured" by obsolescent technology.

To sum up, in understanding the tenacity to survive, we need look no further than our own brain (e.g., Dutton, 1999; *global brain*) for metaphors on coping with rapid and unexpected changes. However, we do need to go a step further in integrating physiological knowledge about the workings of the brain (Weiss, 2000) to practices in implementing training for production workers.

References

Ardekani, M. Y. (1986). Structural adaptations to environments. *Academy of Management Review*, *11*(1), 9–21.

Boulton, W. R., Lindsay, W. M., Franidin, S. O., & Rue, L. W. (1982). Strategic planning: determining the impact of environmental characteristics and uncertainty. *Academy of Management Journal*, *25*(3), 500–509.

Bourgeosis III, U. (1978). The effects of different organizational environments upon decisions about organizational structure. *Academy of Management Journal*, *21*(3), 508–514.

Bourgeosis III, U. (1985). Strategic goals, perceived uncertainty and economic performance in volatile environments. *Academy of Management Journal*, *28*(3), 548–573.

Burns, T., & Stalker, G. M. (1961). *The management of innovation*. London: Tavistock Publications.

Child, J. (1972). Organization structure, environment and performance: the role of strategic choice. *Sociology*, *6*(1), 22.

Cohen, W., & Levinthal, D. (1990). Absorptive capacity: a new perspective on learning and innovation. *Administrative Science Quarterly*, *35*, 128–152.

Dill, W. R. (1958). Environment as an influence on managerial autonomy. *Administrative Science Quarterly*, 409–443.

Downey, H. K., & Ireland, R. D. (1979). Quantitative versus qualitative: environmental assessment in organizational studies. *Administrative Science Quarterly*, *24*, 630–637.

Downey, H. K., & Slocum, J. W. (1975). Uncertainty: measures, research and sources of variation. *Academy of Management Journal*, *18*(3), 562–577.

Duncan, R. B. (1973). Characteristics of organizational environments and perceived environmental uncertainty. *Administrative Science Quarterly*, *17*, 313–327.

Dutton, G. (1999). Building a global brain. *Management Review*, *88*(5), 34–38.

Foo, C. T. (1990a). Corporate productivity strategies: the small versus the large. *Malaysian Journal of Small and Medium Enterprises*, *1*, 1–7.

Foo, C. T. (1990b). Perceptions of corporate productivity practices. *Omega*, *18*(4), 355–363.

Foo, C. T. (1991a). Union presence and corporate productivity practices. *British Journal of Industrial Relations*, *29*(1), 123–127.

Foo, C. T. (1991b). Unionism, bureaucracy and productivity. *Management Review*, *13*(2), 15–20.

Foo, C. T. (1995). Organization HRD and technology: towards a bureaucratic theory of strategic control. *International Journal of Human Resource Management*, *6*(1), 127–141.

Foo, C. T. (1997). The artificial firms: technology, organization and Woodward revisited. *Journal of High Technology Management Research*, *8*(1), 37–61.

Ford, J. D., & Slocum, I. W. (1977, October). Size, technology, environment and the structure of organizations. *Academy of Management Review*, 561–575.

Galbraith, J. (1973). *Designing complex organizations*. Addison-Wesley Publishing Firmsy.

Grinyer, P. H., Ardekani, M. Y., & Al-Bazzaz, M. Y. (1980). Strategy, structure, the environment and financial performance in 48 UK firms. *Academy of Management Journal*, *23*(2).

Jauch, L. R., & Kraft, K. L. (1986). Strategic management of uncertainty. *Academy of Management Review*, *11*(4), 777–790.

Khandwalla, P. N. (1972). Environment and its impacts on the organization. *Studies of Management and Organization*, *2*, 297–313.

Koberg, C. S., Sarason, Y., & Rosse, J. (1996). A taxonomic approach to studying high technology Finns: deciphering the Tower of Babel. *Journal of High Technology Management Research*, *7*(1), 15–35.

Lawrence, P. R., & Lorsch, J. W. (1967). *Organization and environment: managing differentiation and integration*. Harvard University Press.

Leifer, R., & Huber, G. P. (1977). Relations among perceived environmental uncertainty, organization structure and boundary spanning behavior. *Administrative Science Quarterly*, *22*, 235–247.

Milliken, F. J. (1987). Three types of perceived uncertainty about environment: state, effect, and response uncertainty. *Academy of Management Review*, *12*(1), 133–143.

Nicholls-Nixon, C. L. (1995). Responding to technological change: why some firms do and others die. *Journal of High Technology Management Research*, *6*(1), 1–16.

Scott, R. W. (1981). *Organizations—rational, natural, and open systems*. Prentice-Hall.

Sherrington, C. S. (1897). Part III. The central nervous system. In M. Foster (Ed.), *A textbook of physiology, vol. 1117*. London: Macmillan.

Sylwester, R. (1995). *A celebration of neurons*. Canada: Association for Supervision and Curriculum Development.

Terreberry, S. (1968). The evolution of organizational environments. *Administrative Science Quarterly*, *12*, 590–613.

Tung, R. L. (1979). Dimensions of organizational environments. *Academy of Management Journal*, *22*(4), 672–693.

Weiss, R. P. (2000). Brain-based learning. *Training and Development*, *54*(7), 20–23.

Winch, G. (1999). Knowledge management. *Manufacturing Engineer*, *78*(4), 178–181.