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The Speed and Efficiency in R&D Activities: an Empirical Study of Taiwanese IC Industry

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ABSTRACT

This study aims to examine the accumulation processes of R&D resources how to affect the relationship between R&D spending and innovation performance. The dataset of this paper consists of an unbalanced panel of 514 Taiwanese public listed IC firms over an 11 year period from 1998 to 2008. The empirical results show that a great deal of R&D expenditure in a short period of time is useless because of it decreases the benefit of R&D spending on innovation performance. In addition, we also find that firms are able to benefit from the regular accumulation process of R&D deployment over time are also more likely to avoid the diseconomies of time compression.

In addition, this study reveals that the IC company can take advantage by the regular accumulation process of R&D deployment over time and also more likely to avoid the diseconomies of time compression.

Keywords: resources accumulation, time compression diseconomies, innovation performance

研發活動的速度與效率：台灣 IC 產業的實證

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摘　要

本研究旨在探討研發資源的累積過程對研發支出與創新績效之關係的影響。本研究搜集 1998 年至 2008 年間 514 個上市櫃 IC 公司的樣本點。實證結果發現，短時間內大量的研發支出將無濟於事，因為它會降低研發投資對創新績效的貢獻。此外，本次研究還發現企業可以從規律的研發配置中獲益，避免時間壓縮的不經濟。

關鍵詞：資源累積，時間壓縮不經濟，創新績效

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I. INTRODUCTION

Successful innovation improves existing products and processes, thereby contributing to higher productivity, lower costs and increased profits. High-tech industry in particular is a dynamic industry characterized by large investments in research and development (R&D) in an attempt to create new product markets, gain market share, and make resources more productively by innovation. However, firms' innovation capability cannot be bought in factor markets; they must be internally accumulated by sustained investment over time [37]. Therefore, success in competition depends upon the sustained commitment to R&D activities which allows a firm to develop and introduce products and technology faster than their competitors. Hence, high-tech firms place great emphasis on R&D spending in order to gain innovation, which is an important driver of competitiveness and sustained performance [12].

Cohen and Levinthal (1989) assert that firms with a history of increased efforts in R&D commitment over time may produce superior absorptive capacity and maintain innovative capabilities [47]. Such capacities have a cumulative character. The successful development of R&D capabilities will permit more efficient exploitation in the future [17;48], so firms' R&D activities are process dependent. However, R&D investment involves high costs and high risks that cannot produce the desired results in the short-term. In addition, R&D spending is often damages the current financial performance of a firm. Therefore, managers are always deeply concerned about how to guide their R&D commitment in order to attain the best effect. In fact, too much R&D input in a too short period of time can lead to the emergence of the phenomenon of time compression diseconomies. This decreases the efficiency of R&D commitments [13;35;37;51]. In other words, the processes of resource accumulation are subject to time compression diseconomies, making the development of firms' capabilities more difficult and costly. However, the cumulative nature of firms' capacity has not been taken into account by many empirical studies [44]. Hence, this study aims to reconcile resource accumulation theory with empirical evidence.

Drawing on the perspective of time compression diseconomies, this study argues that the contribution of a firm's R&D spending on innovation performance is contingent on processes by which it accumulates R&D resources. Hence, this study explores the characteristics of the accumulation processes of R&D resources, and investigates how the relationship between R&D commitment and innovation performance is moderated by various characteristics of its accumulation processes of R&D resources. In fact, the core argument of the Resource-Based View (RBV) is resource heterogeneity among firms. However, prior studies make for calculational convenience by following the production function. However, firms' resources adopt inputs-based measurements that imply the assumption of resource homogeneity for any firm, which squarely contradicts the logic of RBV [15]. Moreover, this study differs from previous works because we consider the process of resource accumulation based on time compression diseconomies, and examine its moderating effect on the efficiency of R&D spending. This implies that innovation efficiency differs among two firms even when their current R&D spending is equal, because there is a difference in the process by which they accumulate R&D resources. Therefore, the results of our empirical study can provide more knowledge about the processes of the accumulation of resources and how such processes influence the heterogeneity of firms' capabilities.

The sample chosen in this study is Taiwan's IC industry. Since Taiwan is often portrayed as a technological leader in the developing world, Taiwan's IT industry plays an very important role in the global high-tech manufacturing system, and Taiwan has become the fourth largest production center in the world for IC and PC, behind to the United States, Japan and South Korea. In addition, we chose the IC industry as the target sector because the IC industry incurs many major innovation activities and thus has been frequently used in prior studies [7;10]. In addition, patent activity in the IC industry is pervasive, providing a wealth of documentation for knowledge development. Moreover, the purpose of this study is to explore the characteristics of the processes of accumulating

R&D resources and how such processes influence the efficiency of R&D commitments. Hence, the IC industry is selected in this study.

II. LITERATURE REVIEW

According to RBV, the competitive advantage of a firm comes from the outcome of resource selection, accumulation and deployment. Some strategic factors cannot be traded; they can only be accumulated. Moreover, a firm's resources are the outcome of its commitment trajectory and are thus path-dependent [13;28;50]. That is to say, the resource base is the foundation for creating new capabilities and reinforcing current ones. Histories of resource accumulation vary, leading to the existence of the distribution of firms over a potentiality large range of capabilities. Therefore, sustained R&D commitment has become the main path by which firms accumulate knowledge.

A firm's R&D spending contributes to its absorptive capacity and generates new knowledge and innovations [8;47]. However, firms that attempt to invest a great deal of money to develop R&D capability quickly are often unsuccessful because of time compression diseconomies [37;20]. Time compression diseconomies are derived from a micro-model of resource development with diminishing returns for effort. This implies that asset accumulation cannot be rushed [28;36]. That is to say, compressing lots of effort into a short period of time is not as effective as spreading it out over a longer period of time. Hence, the faster a firm develops resources, the greater the cost.

The phenomenon of time compression diseconomies emerges when firm has not yet been able to learn from its resource commitments and apply them [14;20]. In addition, firms' existing structure, process and routines are slow to adapt to resource re-allocation. Resources will be wasted due to inappropriate resource allocation, if the commitment is too fast or too great [35;51]. Hence, a firm can benefit from R&D commitment, but the amount of input they can absorb and put to commercial use is constrained in time.

This study suggests that the process of resource accumulation exhibits the phenomenon of time compression diseconomies, which makes a firm's capability development more difficult and costly. According to the classification proposed by Vermeulen and Barkema (2002), the dimensions of time compression diseconomies can be classified as the pace, scope and rhythm of the process of resource accumulation. The hypotheses inferred in this study follow their classification.

2.1 Pace

The strategic assets of a firm are the cumulative results sustained over a period of time by firm input in order to accumulate them internally. Since a firm's R&D resources are gradually accumulated by sustained R&D commitment, fast input in a brief period of time may lead to the inability to transform input into meaningful learning and strategic assets [14;19]. A high pace of resource accumulation may lead to overload that will limit the ability of a firm to absorb and create new knowledge in the future. Deploying effort over a short period of resource accumulation produces less sustained competitive advantages than efforts invested over a longer period [46].

Since a firm's capabilities is limited by the amount of resource commitment that it can absorb and internalize within a given period of time, time compression diseconomies may emerge depending on the amount of resource input the firm undertakes within a given period of time, i.e., the pace of the processes of accumulating resources [37;51;39]. Similarly, Pedersen and Petersen (1998) found that the pace by which firms commit resources may make their resources differ substantially. In other words, if a firm constructs strategic assets at a high pace, it is less likely to achieve the full potential of its resources commitment. In summary, we derive the following hypothesis:

H1: A faster pace of R&D resource accumulation negatively moderates the impact of a firm's R&D spending on innovation performance.

2.2 Rhythm

Firms' operational activities are embedded, interdependent and, to some extent, fit should be achieved by matching different activities [46]. If a change rate of a given activity of a firm has

greater variability, managers must frequently adjust other activities to match with that of the change [27]. In addition, any operational actions must relate to the resources allocated and used at a particular time. In an irregular path, firm's employees often fail to anticipate change in the future. As a result, managers often have to solve internal coordination problems. Hence, managers come up against a lot of administrative challenges when firms change the level of resource commitments [4]. In contrast, a regular pattern of resource commitment can allow companies to absorb knowledge through habitual steps, and over time can facilitate the formation of a routine [19;27;46]. Such a routine can increase the efficiency of the coordination of business activities, making firms' resource allocation and utilization more effective. Therefore, the differentiated variability pattern among a given activity reflects the chaotic nature of the re-allocation of resources.

In this paper, rhythm refers to the variability of the amount of R&D spending in the accumulation process of R&D resources. This reflects the shape of a firm's R&D commitment over a given period. A firm with spurts of R&D commitment has an irregular rhythm that will damage knowledge accumulation and absorptive capability. Hence, the moderating effect of the irregular pace of past R&D commitment on the relationship between a firm's R&D spending and innovation performance is negative.

H2: A more irregular pace of R&D resource accumulation negatively moderates the impact of a firm's R&D input on innovation performance.

2.3 Scope

No innovation is completely novel in that all technologies are a recombination of previously existing knowledge [22]. Combining existing knowledge and new knowledge is part of the success in the innovation of a firm. Firms possess diversified existing knowledge that offers the ability to rapidly provide widely accessible knowledge. In addition, the diversified knowledge of a firm facilitates the capability of identifying knowledge, which increases the efficiency of searching for external knowledge. Hence, a diversified knowledge base facilitates innovation because diversified knowledge offers a more robust base for learning [24]. This study considered the impact of diversified knowledge on innovation activities. We attempt to identify a firm's existing knowledge which is derived from exploration or exploitation effort, and examine the weight of exploration or exploitation efforts and how such efforts influence a firm's innovation. In addition, firms engaged in M&A activities can access different sources of knowledge and enrich the diversity of knowledge. Hence, the ways in which M&A activities influence firms' innovation is also considered.

2.4 Exploration and exploitation learning

A firms' existing knowledge refers to learning by both exploration and exploitation activities. March (1991) argued that there is a trade-off between exploration and exploitation activities. In other words, if a firm applies more efforts to exploration activities, exploitation activities will be expropriated. Explorative learning emphasizes knowledge generated by exploration activities which are often distant from the existing knowledge base of the firm [26]. Firms will have access to more heterogeneous knowledge when they continuously exert effort in well-explored technological domains for a long time [1;49]. Moreover, firms which possess diversified knowledge often provide energy absorptive capabilities superior to those firms whose knowledge has a tendency towards convergence [13]. Therefore, R&D commitment increases efficiency when a firm has diversified knowledge and engages in active exploration activities. In addition having superior absorptive capability, firms with diversified knowledge often have more opportunities for success through the combination of different knowledge areas, which facilitates innovation.

In contrast, exploitative learning refers to the exploitation of existing knowledge of a firm. The accumulated knowledge of firms has limiting variety of exploitative learning [32]. The existing knowledge had been in existence for some time and the characteristics are relatively well understood when knowledge is increasingly exploited. Furthermore, the potential for the combination of factors will

already have been explored and been put to wider usage. As a result, there are fewer opportunities for further recombination, giving rise to decline in innovation [1;22]. Hence, this reasoning leads to the following hypothesis:

H3: Greater effort in the exploration of existing knowledge positively moderates the impact of a firm's R&D input on innovation performance.

2.5 External knowledge internalization

Innovative activity and technological development are likely to give rise to a path dependent process of knowledge accumulation, whereby the district itself is at risk of a lock in the collective learning processes (i.e., core rigidities). Core rigidity is harmful to organizational learning; it even endangers firms' competitiveness within their industry [29]. This may lead to core rigidities within internal technological development and destroy existing competencies when firms focus on a few core capabilities. In order to overcome the crises caused by core rigidity, firms can increase the stock of knowledge produced by combining external knowledge with internal knowledge. M&As are a well-recognized method for rapidly capturing desirable resources. M&As can serve as a major channel for reorganizing R&D activities since they enable firms to quickly expand their knowledge base by accessing new technological assets [3].

M&A can create one-way or two-way diffusion of knowledge between acquiring and acquired firm. It allows an acquiring firm to transfer its own knowledge to a target firm and provide other uses for its R&D and production capabilities [6;3]. In addition, the acquiring firm can also acquire skills and resources from the acquired firm, i.e., reverse internalization [45]. In other words, in effect the acquirer 'grafts' the product innovation capacities of the target firm onto their own asset base. Moreover, M&A also complements their internal product development efforts. The value creation logic of M&A leverages acquirer strength in conjunction with the target firm's innovation capabilities [42]. Therefore, firms that engage in M&A activities can attain higher efficiency from their R&D commitment than firms that do not engage in M&A activities.

H4: M&A positively moderates the impact of a firm's R&D spending on innovation performance.

III. RESEARCH DESIGN

3.1 Sample

This study explores that the process by which firms accumulate R&D capability and how such a process influences the efficiency of sequential R&D input. Firms' capacities are path dependent and reflect the cumulative processes of a firm's resources, Longevity contributes directly to this track record and can provide more insight into the history of a firm's resource accumulation. In addition, limiting the analysis to a single industry insures that the dimensions of a firm's resources which are characterized are of comparable importance. It is the best explored empirically in the context of a large sample of firms drawn from a single industry. This study chose the IC industry as the targeted sector because the IC industry incurs many major innovation activities and thus has been frequently used in prior studies [17]. Up until this time, the make of IC still use the 65 nm design, the manufacture process reached its maturity in 2008. That year was also the turning point for wafer fabrication production. During the Asia financial crisis in 2008, IDM Texas Instruments merged massive IC firms, since then Texas has become the paradigm IC firm among all.

Hence, the hypotheses of this study were tested with longitudinal data for 514 Taiwanese public listed IC firms over an 11 year period from 1998 to 2008.

$$Patent_i = \exp(\beta_1 RDS_i + \beta_2 Pace_i + \beta_3 Rhythm_i + \beta_4 Explore_i + \beta_5 Merger_i + \beta_6 RDS_i \bullet Pace_i + \beta_7 RDS_i \bullet Rhythm_i + \beta_8 RDS_i \bullet Explore_i + \beta_9 RDS_i \bullet Merger_i + \sum_j \gamma_j Control_{ij} + \varepsilon_i) \quad (1)$$

3.2 Model Specification

The dependent variable of this study is innovation performance measured by patent counts. This variable takes only discrete non-negative integer values. Because of the limited nature of the dependent variable, this study employs a Poisson models to test the

hypotheses [40;23]. The following model will be tested in the next section:

Where *Patent* is the number of patents. *RDS* is measured by the nature log transformation of R&D spending. *Pace* is measured by the last five-year average R&D spending. *Rhythm* is measured by the standard deviation of R&D spending over the last five years. *Explore* is measured by the count of invention patents divided by the count of total patents. *Merger* is a dummy variable which equals 1 if a firm accomplishes its M&A deal 3 years before the study year, and 0 otherwise. *Control* is a vector of control variables affecting *Patent*, which includes firm size (*SIZE*), firm age (*AGE*), financial slack (*Debt*) and the year dummy variable.

3.3 Measures

3.3.1.Dependent variable

Patent count is a direct measure of the output of the R&D commitments carried out by the firm. Prior studies have widely used patent statistics to evaluate innovation performance, and this study also used the count of patents as a measure of innovative performance [1;3;40;25]. Moreover, a lag of one year indicates that the dependent variable should not be confused with cause and effect between dependent and independent variables. Moreover, the count of the firms' patents was obtained from the *Taiwan Patent Search database of Taiwan's Intellectual Property Office*.

3.3.2 Independent variables

Cohen and Levinthal (1990) focused mainly on the role of R&D spending in building absorptive capacity and point to the role R&D plays in building absorptive capacity and generating new knowledge and innovations for firms. Following their concept, this study adopts R&D spending as a proxy for R&D commitment [28]. This study measured the R&D spending of a firm in a given year by nature log transformation, in order to stabilize the variance of a sample. The R&D spending was obtained from the *Taiwan Economic Journal Data Bank*.

The dimensions of 'learning processes' based on the time compression diseconomies can be observed by the pace, scope and rhythm of resources accumulation [51]. Firstly, in this study, pace indicates the amount of R&D spending that a firm undertakes in a certain period of time. In this study, the average R&D spending is used to measure the pace of resource accumulation. This study also used the nature log transformation of average R&D spending over the five-year period.

Secondly, standard deviation is a statistical measure that provides a good indication of volatility. Such an indicator can measure how widely values are dispersed from the mean. In this study, the rhythm of resource accumulation of a firm was measured through the standard deviation of the logarithmic transformation of R&D spending based on the data for the 5 years proceeding the nomination year.

Thirdly, this study proposes that a wide scope of existing knowledge will affect the absorptive capability of a firm [47]. Explorative learning emphasizes learning by knowledge generated by exploration activities. This type of learning is often distant from the existing knowledge base of the firm. In contrast, exploitative learning is closely related to the existing knowledge base [32]. Moreover, firms exploration and exploitation learning is a trade-off relationship [31]. Hence, we adopt *EXPLORE* as a proxy of exploration learning. It is measured by the count of invention patents divided by the count of total patents.[1] The time window is adopted that over the past four-year period as done in previous studies [2;11]. The

[1] According to the provisions of the ROC Patent Act, "patents" are classified into three forms, invention patents, utility model patents, and design patents. Firstly, an invention patent refers to any creation of technical concepts by utilizing the rules of nature. This type of patent has a protection term of twenty years and is analogous to a utility patent in the United States. Secondly, a utility model patent is a creation of technical concepts that utilizes the rules of nature to reflect the innovation of a form, construction, or installation of an article that possesses a new purpose or improved efficacy. It has a protection term of ten years and is most similar to a U.S. improvement patent. Finally, a design refers to any creation made in respect of the shape, pattern, color, or combination thereof of an article through visual appeal. This type of patent has a term of twelve years and is similar in function and scope to a design patent in the United States.

count of related patents was also acquired from *Taiwan Patent Search database of Taiwan's Intellectual Property Office*.

Finally, merger and acquisition is one of the most effective strategies to gain technological capabilities. M&A can affect a firm's R&D input and outcome, as documented in previous studies [3]. Therefore, high-tech firms often adopt the acquisition strategy in order to gain external knowledge [43]. Therefore, firms' M&A activities were considered in this paper. The variable was a dummy variable coded 1 for firms that had engaged in M&A in the last three years, and 0 otherwise. The M&A activity was obtained from the *Market Observation Post System* database the day before the announcement.

3.3.3 Control variables

This study used a number of control variables to ensure the reliability of the effect of various factors that were included in the model. Firstly, firm size is an important factor. Larger firms may have more resources and greater ability to sustain resources commitments [16]. In addition, large firms may provide advantage in the conduct of R&D efforts or their innovation activities [30;33]. Hence, this study controlled the effect of firm size in order to decrease the possible influence on the empirical results. We used the nature log transformation of total employees as the proxy indicator for firm size.

Secondly, the innovative abilities of a firm may improve with time because a firm's innovative activities may be subject to learning effects. Moreover, firms' age typically is the proxy indicator of firm experience. Therefore, this study controls the impact of organization age on innovation performance. The organization age was measured as the number of years that had passed since the firm was first founded.

Thirdly, failing to maintain sufficient financial slack can seriously inhibit a firm's ability to successfully implement a strategy. The existence of slack provides potential resources for creative behaviors such as R&D activities [5]. Hence, this study also considers firms' slack, and the debt to equity ratio was proxied as the absorbed slack that reflects the healthiness of the balance sheet and borrowing capability [21]. This variable measures the ratio of total equity to total liabilities.

Finally, this study utilizes longitudinal data for Taiwanese IC firms over an 11-year period from 1998 to 2008. Hence, we constructed nine year dummies in order to control year effect.

IV. RESULTS

4.1 Descriptive statistics

Table 1 provides the sample statistics and correlation coefficients for the independent variables across the samples. It indicates that the highest correlation coefficient between any two independent variables is 0.701, which deviates from the range of acceptance. In order to reduce the multicollinearity between the main and interaction terms in the estimated model, the continuous independent variables are centered. In addition, this study will adopt a robust estimate using Poisson regression.

Table 1. Sample statistics and correlation matrix

	Mean	S. D.	1	2	3	4	5	6	7
1 SIZE	5.82	1.77							
2 AGE	14.42	7.32	.19 **						
3 Debt	2.11	4.83	-.23 **	.02					
4 RDS	.25	.72	.32 **	.06	-.04				
5 Pace	.25	.75	.29 **	.12 **	.01	.70 **			
6 Rhythm	-.05	.93	-.07	-.13 **	.00	-.30 **	-.64 **		
7 Explore	.03	.98	-.01	-.12 **	.03	.32 **	.30 **	-.13 **	
8 Merger	.20	.40	.18 **	.09 **	-.01	.15 **	.16 **	-.07	.07

Table 2 presents the results for the robust Poisson regression model. Model 1 shows coefficient estimates for the control variables. Models 2-5 display the effects of each interaction item added in sequence to the control variable model. Model 6 displays the results of the full model.

Hypothesis 1 predicts that the pace of R&D resource accumulation negatively moderates the impact of a firm's R&D spending on innovation performance. As shown in Model 2 and Model 6, the coefficient for *RDS × Pace* are negative and significant. This evidence supports Hypothesis 1. This implies that a great deal of R&D expenditure in a short period of time will be wasted because of it will decrease

the contribution of R&D spending to innovation performance.

In addition, Hypothesis 2 predicts that an irregular accumulation process of R&D resources decreases R&D efficiency. In Model 3 and Model 6, the impact of the R&D spending and rhythm interaction items on the innovation performance is negative and highly significant. This result suggests declining R&D efficiency leads to more variance in the amount of R&D commitment. Accordingly, the results provide support for Hypothesis 2.

Hypothesis 3 predicts that a firm that is more involved in explorative R&D activities will increase R&D efficiency. However, Model 4 and Model 5 display that when a firm's R&D commitment is over engaged in explorative R&D activities, its R&D efficiency would be decrease. That is, the positive effect of R&D spending on innovation performance is mitigated with an increase in the involvement of exploration R&D activities. Therefore, Hypothesis 3 does not gain support in this study.

Finally, Model 5 and Model 6 indicate that there is a positive and significant relationship between M&A activity and innovation performance. In other words, a firm engaged in M&A activity will contribute to innovation performance. However, the interaction between the M&A activity and R&D commitment shows no effect on innovation performance. Hence, the results do not support Hypothesis 4.

Table 2. Poisson Regression analysis

	Model 1	Mode 2	Model 3	Model 4	Model 5	Model 6
RDS × Pace		-1.409 ***				-1.899 ***
RDS × Rhythm			-0.485 ***			-1.847 ***
RDS × Explore				-0.553 **		-0.225
RDS × Merger					-0.133	-0.027
RDS	2.084 ***	3.291 ***	1.999 ***	2.309 ***	2.151 ***	3.495 ***
Pace	0.859 *	1.723 ***	0.801 *	0.929 *	0.840	1.819 ***
Rhythm	0.129	0.194	0.259	0.165	0.124	0.907 ***
Explore	0.034	-0.122	0.047	0.223 *	0.035	-0.039
Merger	0.524 ***	0.492 ***	0.538 ***	0.506 ***	0.641 **	0.538 *
age	-0.007	-0.006	-0.008	-0.006	-0.007	-0.008
slack	-0.005	0.014	-0.008	-0.003	-0.005	0.015
size	0.300 ***	0.357 ***	0.296 ***	0.304 ***	0.298 ***	0.369 ***
Year effect	control	control	control	control	control	control
Constant	0.012	-0.858 *	0.069	-0.049	-0.026	-0.963 **
N	514	514	514	514	514	514
Log likelihood	-9297.756	-8895.836	-9250.565	-9149.874	-9291.509	-8545.243
Pseudo R^2	0.791	0.800	0.792	0.794	0.791	0.808
Wald chi^2(df)	1284.47(18)	1343.11(19)	1498.96(19)	1298.48(19)	1355.05(19)	1349.93(22)

4.2 Discussion

The accumulation process of firms' resources described in previous studies suggest that that firms produce their resources from stock of existing resources and current period investments [28]. This study focused on the accumulation process of R&D resources and how such a process influences a firm's absorptive capability. We argue that the contribution of the current R&D spending on innovation performance is contingent on the processes of accumulating R&D resources. Drawing from the perspective of time compression diseconomies, this study aims to make predictions about how the pace, rhythm and scope of the accumulation process of R&D resources influences the efficiency of the sequential R&D spending of a firm. Taiwan's IC industry is adopted to test the interactions of

the effects of R&D spending and the accumulation process of R&D resources.

Consistent with our predications, we found that the pace of accumulation processes negatively moderates how much a firm benefits from current R&D spending. In other words, the positive impact of R&D spending on innovation performance is mitigated by the speed of R&D resource accumulation. This implies that when a firm invests in R&D activities with a steady speed, they will create more efficient accumulation.

Our study also observes that an irregularity in resource accumulation will decrease the contribution of sequential R&D spending on innovation performance. That is, irregular investment in a firm's R&D activity leads to more inefficient resource accumulation. In contrast, a regular pattern of commitment to resources can allow companies to absorb knowledge in a habitual pattern, and over time can facilitate firms' effective accumulation of resources. This will facilitate the efficiency of sequential R&D investment.

In addition, this study predicts that the more a firm is involved in explorative R&D activities, the more it will increase the efficiency of sequential R&D investment. However, that assertion did not gain support. We found that the R&D spending of firms that engaged in more explorative R&D activities contributed less to innovation performance than the firms that engaged in more exploitative R&D activities. In fact, according to the RBV, a firm's competitive is derived from firm-specific resources that result from internal accumulation which is a key feature of exploitative search. Therefore, RBV asserts that an exploitative search is generally more desirable than an explorative search [52]. This may explain why the empirical effects could not support Hypothesis 3.

Last, we found that there is no interaction effect between M&A and the efficiency of R&D spending. However, we observed that the impact of M&A on innovation performance is a main effect. This is because internally accumulating capabilities for producing streams of innovation is a time consuming, path dependent and uncertain process [43]. Through a merger, a firm can directly acquire R&D resources from the target firm. Thus, previous studies show that M&A might lead rapid improvement in a firm's innovation performance since firms can directly obtain R&D resources [3;41]. This could explain why the empirical effects do not support Hypothesis 4.

V. CONCLUSIONS

Absorptive capacity is accumulated by the sustained R&D commitment of a firm. However, R&D investment involves high costs and high risks, and cannot produce the desired results in the short-term. In addition, too much R&D input in a too short period of time can lead to the emergence of time compression diseconomies. This will decrease the efficiency of R&D spending. Hence, this study draws from the perspective of time compression diseconomies, and examines the characteristics of the accumulation process of R&D resources how and such a process influences the R&D efficiency of R&D spending. Our data set consists of 514 publicly traded IC firms over 1998 to 2008.

The results support the suggestion that the pace of the accumulation process of R&D commitment negatively moderates the efficiency of sequential R&D spending. That is, the positive effect of R&D spending on innovation performance is mitigated by increasing the pace of R&D resource accumulation. We also found that a more irregular pace of R&D resource accumulation negatively moderates the impact of a firm's R&D input on innovation performance. In addition, we found that when a firm's R&D commitment is over engaged in explorative R&D activities, there is a decrease in its R&D efficiency. Finally, there is a positive and significant relationship between M&A activity and innovation performance shown in our empirical study. In other words, the main effect of a firm engaging in M&A activity is to contribute to innovation performance.

Although, the results of this study can assist firms in identifying the R&D commitment to adopt effective facilitate capability accumulation, however, this study only adopted the research from 1998 to 2008. The follow up research are suggested to use a longer research time or to compare between different research time periods In addition, this study applies the secondary data to conduct the empirical study. For the reasons

that the secondary data has its limitations, the follow-up research by case study can dig deeper into this research topic.##

In addition, this study found that the positive effect of R&D spending on innovation performance is mitigated by the increase in the involvement in exploration R&D activities. In principle, if a firm is more involved in exploration R&D activities for a long time, it can attain easily accessible diversified knowledge, and hence, facilitate sequential R&D efficiency. Hence, this study suggests that future studies can re-examine the direct relationship between exploration R&D activities and performance. This may be a non-linear relationship.

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