New Product Development Efficiency and Firm's Financial Performance: Perspective of Technology Trajectories in Japanese Manufacturing

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Abstract This empirical research intends to explore NPD efficiency and relevant aspects for Japanese manufacturing industries through the perspective of technology trajectories. Employing Pavitt's technology trajectories model [1], four groups of industries are classified: supplier-dominated, scale-intensive, science-based, and specialized suppliers. The relationship between NPD efficiency and firm's financial as well as its difference among technology trajectories are also investigated. For the field work, New Product Development Scorecard (NPDSC) was utilized as a data collecting and analysis tool for 396 participated firms from 14 Japanese manufacturing industries. As a result, it is confirmed that technology trajectories influence the critical NPD operations that contribute to development efficiency. The results also suggest that science-based group possesses the highest NPD efficiency level comparing to other groups. The levels of NPD efficiency for science-based and specialized suppliers are significantly higher than supplier-dominated group. In contrast with earlier studies, scale-intensive group in case of Japan is found that possesses higher level than supposition. It is also found that NPD efficiency positively relates to firm's financial performance. Particularly, improving NPD efficiency in science-based group can make larger contribution to financial performance than other ones. Consequently, this research provides the managerial implication by demonstrating the guidance of NPD operations which are critical for enhancing the development efficiency as well as financial performance in each group.
Key words New Product Development (NPD), NPD efficiency, technology trajectories, financial performance

1 Introduction

New Product Development (NPD) efficiency is one of the most vital performances to determine firm's competitiveness and survival [2],[3]. Firms in various industries, therefore, try to improve their development efficiency to be success in the business. In accordance with this, several researchers have explored the key factor contributing to NPD efficiency. The results suggested that technology is an essential factor that constitutes development efficiency of new product ([4]-[7]). Learning for this exploration, firms can know that which factor they should importantly focus. However, the implication in term of factor level alone might not enough to compete in the dynamic business environment in this era. Extending from this point, further analyses are necessary in order to explore more specific implications for firms in enhancing their development efficiency.

Since the fundamental and source of technology are different by industries. Thus, according to the importance of technology on NPD efficiency, firms need to know that how different technology sources affect on the development efficiency and firm's financial performance. To capture the differences of technology among industries, the technology trajetories model from Pavitt's [1] is adopted in this research. According to this model, valuable information about sources and directions of technology as well as the dynamic relationship between technology and industrial classification are provided. With respect to Pavitt study, several scholars in European countries have rectified his model by examining through the relevance aspects of innovations within their dataset [8], [9] as well as explored additional category of technology trajectories [10], [11]. To the authors' knowledge, there is very few research directly examining the influence of technology trajectories on NPD context, particularly in the aspect of NPD efficiency. Besides, this research is the first elaboration of Pavitt's model to the dataset of Japanese manufacturing.

Consequently, this research aims to explore the NPD efficiency for Japanese manufcaturing industries, by investigating through the perspective of technology trajectories. The critical NPD operations for development efficiency are also revealed. The results are expected to help firms from different sources of technologies in appropriately set the specific strategies and operations to improve development efficiency for successfully competing in their markets. In addition, addressing firm's business value, the contribution of NPD efficiency on firm's financial performance as well as its difference among trajectories are also investigated in this research.

2 Research Methodology and Hypothesis

2.1 New product development scorecard (NPDSC) and data collecting process

NPDSC was initiated by Japan Organization for Quality Innovation (JOQI) in 2001. NPDSC is designed for being self-NPD performance assessment tool covering all manufacturing industries in Japan. The scorecard encompasses 25 assessment items based on four core assessment areas: (1) Organizational Systems of Development, (2) Planning and Execution Ability, (3) New Product Development Performance, and (4) Exploitation of management tools and information technology. Each of assessment item is rated according to five defined levels (with detailed description), with the 5th level supposing to be the best practice. (see Appendix 1). Additionally, the result of assessment from NPDSC for individual company could be compared against competitors in the same industry as well as across the industries.

Owing to the data collecting process, NPDSC has been used to collect data by interviewing method from participated firms in Japan manufacturing sector since 2003 [12], then by maling method in 2007 [5]. Finally, total of 625 samples (from 396 companies including multiple assessors and industries categories selections) were obtained, as shown in Table 1.

2.2 Industries classification by technology trajectories

Pavitt [1] has classified firms into the four categories of technological trajectories by considering several indicators, as followings: the industrial sector, the source of technology, the type of user of technology, the means of appropriation, the relative balance between product and process innovation, as well as the intensity and direction of technological diversification. According to the definition of industry classification from Pavitt, by focusing on the aspect of source and direction of technology, four groups of industries were classified in this study, as shown in Table 1. These are: ***(1) Supplier-dominated;*** Technological change comes almost from suppliers of machinery and other production inputs, ***(2) Scale-intensive;*** Technology is incrementally accumulated from the basis of earlier experience, and internal improvements, ***(3) Science-based;*** Technology accumulation mainly generates from R&D activities of firms, and is heavily dependent on knowledge, skills and techniques emerging from academic research, ***(4) Specialized suppliers;*** Technological accumulation takes place through the design, building of specialized inputs that will be provided to next customer.

Table 1 Industries Classification by Technology Trajectories

Industry	Number of samples	Supplier-dominated	Scale-intensive	Science-based	Specialized suppliers
1 Construction	58		●		
2-1 Processed Food	4	●			
2-2 Beverage & Liquor	0	●			
3 Cloth & Apparel	7	●			
4-1 Wood & Furniture	12	●			
4-2 Paper & Plup	7	●			
4-3 Printing	4	●			
5-1 Pharmaceutical	8			●	
5-2 Chemistry for General Use	19			●	
5-3 Chemistry for Business Use and material	79				●
6 Iron-Steel & Nonferrous metal	47	●			
7-1 Machinery & Appliances for General Use	26			●	
7-2 Machinery & Appliances for Business Use	57				●
8-1 Electrical Machinery & Appliances for General Use	36			●	
8-2 Electrical Machinery & Appliances for Business Use	68				●
9 Information Communication	15			●	
10-1 Automobile & Motorcycle	16		●		
10-2 Ship & Other transportation	11		●		
11-1 Precision Machinery & Appliances for General Use	10			●	
11-2 Precision Machinery & Appliances for Business Use	40				●
12-1 Electronic Part & Devices for Auto Industry	22			●	
12-2 Electronic Part & Devices for Others	26			●	
13-1 Machinery Part for Auto Industry	27				●
13-2 Machinery Part for Others	12				●
14 Software	14				●
Total	625	81	85	162	297

2.3 Research hypothesis

Souitaris [13] has confirmed that firms in different technological trajectories (with regard to Pavitt's classification) have significant differences in the determinants of innovation. Since innovation is used to describe a new breakthrough in a process technique or a novel product [14], thus, the effect of different technoloy trajectories could also be examined in the context of NPD, as well. Focusing on NPD efficiency, it is mainly constituted by the technology of firms ([4]-[7]). Firms who have different fundamental and source of technology require different strategic implications [14]. Therefore, firms may also require different critical operations or practices to improve development efficiency in each group. Undelying this point, the first hypothesis is established.

Hypothesis 1: The critical NPD operations which constitute NPD efficiency in each group typically depend on technology trajectory.

In the later study of Pavitt et al. [15], it is indicated that rate of innovation (the number of innovations), was higher in science-based and in specialized suppliers firms, and was lower in supplier-dominated firms. Then, Souitaris [13] further confirmed this finding and found that rate of innovation was also lower in scale-intensive firms, as well. In general, development efficiency refers to development productivity and capability of man-power management that will consequently affect on rate of new product output. Thus, the number of innovations may correspond to development efficiency of new product in the same pattern. From this sense, the second hypothesis is proposed.

Hypothesis 2: "Science-based" and "specialized supplier" firms possess higher NPD efficiency level than "supplier -dominated" and "scale-intensive" ones.

Development efficiency of new product could contribute to successful NPD which is critically important to a firm's financial performance [16],[17]. Among four groups of technology trajectories, science-based group is considered as high technology sector with the highest number of patents [13]. Some industries of this group, such as, pharmaceuticals and chemicals heavily rely on internal R&D. This makes them have the opportunity to earn more benefit from higher share of innovating business units [10]. In addition, several researches suggested that such kinds of these industries could obtain the greatest value from putting the importance of NPD efficiency improvements [2],[18]. In accordance with these literatures, the third and fourth hypothesis are derived.

Hypothesis 3: Development efficiency positively relates to firm's financial performance

Hypothesis 4: Improving NPD efficiency in science-based firms contribute to larger amount of firm's financial performance increase, comparing to firms in the others.

For clearly understanding, it should be noted that the NPD terms as stated in above hypotheses were linked to the framework of NPDSC assessment. Since each assessment item could be considered as either NPD performance or operation. Hence, the NPD efficiency performance would be represented by the assessment item of 3-(3) Development efficiency. Meanwile, the rest of 24 assessment items would stand for the NPD operations.

3 Analyses and Results

According to the first hypothesis, multiple regression analyses were conducted in section 3.1 and 3.2, to identify the critical NPD operations which constitute development efficiency for all samples and for each group of technology trajectory. For hypothesis 2, one-way ANOVA was carried out in section 3.3 to examine the different NPD efficiency level among groups of technology trajectories. Finally, for hypothesis 3 and 4, regression analyses were performed again in section 3.4 to investigate relationships between NPD efficiency, financial performance and technology trajectories.

3.1 NPD operations for development efficiency

In order to identify the NPD operations for development efficiency, regression analysis was conducted for all samples by setting item 3-(3) development efficiency as the dependent variable and taking up rests of 24 assessment items as the independent variables. Then, backward variable selection method was used. The remained items in the model represents for NPD operations which directly impact on development efficiency. The result of regression analysis was shown in Table 2.

Table 2 NPD Operations for Development Efficiency for All Samples

Development Efficiency (All samples, N=625)	B	t-value	*p* -value
(Constant)	-0.454	-4.338	0.000
1-(1) Strategy and resource	0.108	3.399	0.001
1-(4) Needs of cus. and mkt.	0.085	2.279	0.023
2-(1) Quality of planning	0.102	2.333	0.020
2-(3) Project management	0.148	4.085	0.000
3-(5) Design for Envi.	0.071	2.242	0.025
3-(6) NP ramp-up smooth.	0.144	3.579	0.000
4-(1) QFD	0.065	2.004	0.046
4-(2) DFM	0.141	3.197	0.001
4-(4) CAD	0.075	2.491	0.013
R=0.732, R2=0.535, Adj.R2=0.528, Std.Error of Estimate=0.560			

From Table 2, there are nine NPD operations that still exist in the model. It implies that these NPD operations could directly contribute to development efficiency performance. Besides, the set of these operations might be considered as the guidance of common operation for improving NPD efficiency for firms in various manufacturing industries in Japan. According to these operations, *project management* and *NP ramp-up smoothness*, might be regarded as critical NPD operations by considering the distinctive significance of *p*-value. Firms might have to put the importance on both critical operations as priority in order to upgrade their NPD efficiency. In accordance with this, further explanation to clarify the crucial contribution to development efficiency are stated here. Firms who can better manage NPD project and well prepare to face with unforeseen circumstances, they will be able to achieve higher development efficiency. In addition, by supporting of production engineering and source stream management, firms would be able to control the early-stage of production control period close to zero (ramp-up smoothness) that will consequently enhance their NPD efficiency. Finally, the model of these NPD operations would be used as the reference model for investigating the different crucial NPD operation in each technology trajectories.

3.2 Critical NPD operations for development efficiency in each group of technology trajectory

The separate regression analyses for each group according to the classification of technology trajectories were conducted. Same methodology as all samples was used. The results of regression analyses (Table 3- 6) would be compared to the reference model in Table 2, in order to indentify the typical NPD operations that might be vital for each group.

Table 3 NPD Operations for Development Efficiency for Supplier-dominated group

Development Efficiency (Supplier-Dominated, N=81)	B	t-value	*p* -value
(Constant)	0.160	0.892	0.375
1-(1) Strategy and resource	0.172	2.555	0.013
1-(2) Patent and partnership	-0.328	-3.904	0.000
2-(3) Project management	0.302	3.649	0.000
2-(4) DR	-0.289	-3.445	0.001
2-(7) Design rationale	0.262	2.774	0.007
3-(5) Design for Envi.	0.352	4.655	0.000
4-(1) QFD	0.466	5.843	0.000
4-(2) DFM	-0.393	-3.946	0.000
4-(6) Use of open standard	0.156	2.454	0.017
R=0.861, R2=0.742, Adj.R2=0.701, Std.Error of Estimate=0.407			

As a result from Table 3, for Supplier-dominated group (SD), the typical NPD operations which are different from the reference model are *use of open standard* and *design rationale*. Since firms in SD generally leave accumulated technological skills and strategic initiatives to their suppliers. Therefore, utilizing the standard data, information of technology, machinery and production input via the supporting of information technology between firms and their suppliers might be able to improve the development efficiency of new product. Besides, based on supplied technology from supplier, development efficiency might also be contributed by the record and sharing of design and decision making on NPD in the design rationale system among related departments within firms. However, the negative effect are found in the operations of *patent and partnership*, *Design Review (DR)*, and *Design For Manufacturing (DFM)* . These negative results might be dominated by the additional operations

(Herein, *use of open standard* and *design rationale*) which typically showed in this regression model. In this sense, the interpretation might be made through the comparison of implementation priority between the additional positive items and negative items. This means that, in order to improve development efficiency, firms should put the importance on the additional positive operations of *use of open standard* and *design rational,* rather than emphasizing on these negative ones. Nevertheless, among these negative operations, surprising negative result is *DFM* which is opposite to the finding from all samples. With respect to Suwannaporn [19], for such kind of industry in SD (e.g., food industry), development of manufacturing technology for NPD depends on expertise acquired from machinery and equipment suppliers, rather than internal R&D. This might explain why conducting *DFM* by SD firms themselves might not directly contribute to development efficiency comparing to rely on provided manufacturing technology and to focus on technical standard data exchange between suppliers as well as the design rationale system, instead.

Table 4 NPD Operations for Development Efficiency for Scale-intensive group

Development Efficiency (Scale-Intensive, N=85)	B	t-value	*p* -value
(Constant)	-0.587	-2.642	0.010
1-(1) Strategy and resource	0.322	4.205	0.000
4-(1) QFD	0.193	2.214	0.030
4-(2) DFM	0.278	2.611	0.011
4-(5) PDM	0.250	2.741	0.008
R=0.816, R^2=0.666, Adj.R^2=0.648, Std.Error of Estimate=0.584			

From Table 4, for Scale-intensive group (SI), the typical NPD operation which is different from the reference model is *Product Data Management (PDM)*. As mentioned in the typical patterns of firms' innovation behavior by Pavitt [1], firms (for instance, in automobile industry) in this group usually rely on process technology that comes from in-house development. Developing new product in this group will concern to incremental development of their technology and production engineering as well as learning and expereince on their own. Therefore, *PDM* which could react to enable effective use of data responding to the technological change might be considered as vital operation to constitute development efficiency for firms in this group.

Table 5 NPD Operations for Development Efficiency for Science-based group

Development Efficiency (Science-Based, N=162)	B	t-value	*p* -value
(Constant)	-0.504	-2.309	0.022
1-(1) Strategy and resource	0.129	2.464	0.015
1-(4) Needs of cus. and mkt.	0.179	2.443	0.016
1-(6) HRD and developt. org.	0.190	2.019	0.045
2-(3) Project management	0.194	2.667	0.008
2-(4) DR	-0.150	-1.923	0.056
3-(6) NP ramp-up smooth.	0.174	2.349	0.020
4-(2) DFM	0.290	3.596	0.000
R=0.748, R^2=0.559, Adj.R^2=0.539, Std.Error of Estimate=0.550			

According to Table 5, for Science-based group (SB), the typical NPD operation which is different from the reference model is *Human Resource Development (HRD) and development organization*. This finding corresponds to the characteristics of industries in this group (such as pharmaceutical, chemical, and electronic industry) which technologies mainly come from the internal R&D as well as knowledge, skills, and techniques of firm's staffs. They generally adopt know-how from public science and academic sector. In addition, Souitaris[13] suggested that for SB firms, one of the most important determinants of innovation is education and experience of personnel. This is the vital requirement for understanding and developing in-house technology. In this sense, development of human resource and organization might be critical to bring better development efficiency of new product for firms in this group.

Table 6 NPD Operations for Development Efficiency for Specialized suppliers group

Development Efficiency (Specialized Suppliers, N=297)	B	t-value	*p* -value
(Constant)	-0.426	-2.738	0.007
1-(4) Needs of cus. and mkt.	0.165	3.119	0.002
2-(1) Quality of planning	0.179	2.885	0.004
2-(3) Project management	0.153	2.985	0.003
3-(6) NP ramp-up smooth.	0.144	2.750	0.006
4-(2) DFM	0.154	2.448	0.015
4-(4) CAD	0.106	2.400	0.017
R=0.693, R^2=0.480, Adj.R^2=0.469, Std.Error of Estimate=0.559			

As shown in Table 6, for Specialized suppliers group (SS), although there is no typical different NPD operation in this group. The critical operation might also be observed in the regression model. Considering highest significant of *p*-value, *needs of customer and market* showed the strongest of positive impact to development efficiency. According to the feature of industries in SS (such as software, and businesss to business industries), main source of technology are generated from the specific customer requirements. Emphasizing on customer will effectively support firms in this group to develop responsed technologies which consequently contribute to development efficiency of new product.

From the findings in this section, it could be observed that the critical NPD operations for development efficiency in each group are different. It might conclude that vital NPD operations, which contribute to development efficiency for firms, rely on their technology trajectories. Therefore, hypothesis 1 might be supported.

3.3 Different level of NPD efficiency among group of technology trajectory

In this section, according to hypothesis 2, one-way ANOVA was performed in order to find the significant difference of development efficiency among each group. The results of differences were shown in Fig. 1and Table 7.

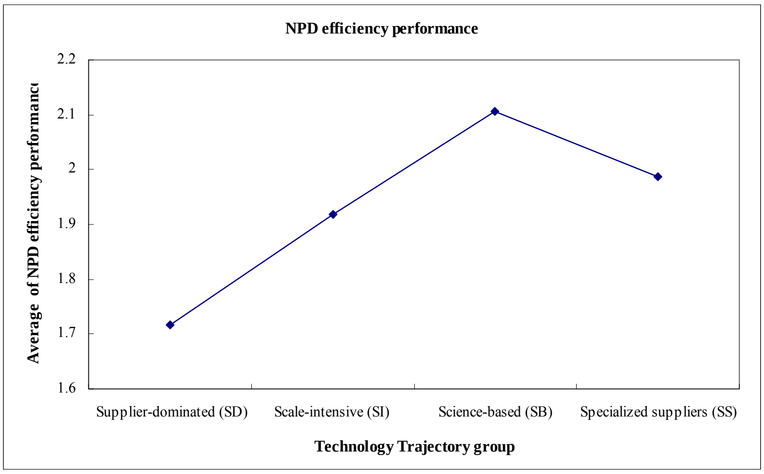

Figure1 Level of Development Efficiency Performance for each group

Table 7 ANOVA Result of Different Development Efficiency Level among four groups

DV: Development Efficiency, Factor: Technology Trajectories classification

Variable	SD	SI	SB	SS	*F*	Differences between group
Development Efficiency	1.716	1.918	2.105	1.987	4.300**	SB>SD, SS>SD

Level of significant **=0.01

SD: Supplier-dominated, SI: Scale-intensive, SB: Science-based, SS: Specialized-suppliers

As shown in Fig. 1, SB possesses the highest level of development efficiency performance. Besides, from Table 7, the development efficiency level for SB and SS are significantly higher than SD, but not significance comparing to SI. As suggested by Souitaris [13], SB and SS are considered as high-innovation trajectories, while the rest ones are low-innovation trajectories. In accordance with this, high-innovation trajectories usually enroll with the pressure of technology development. For SB, firms generally have to catch up with rapid development of the underlying science and knowledge in the universities and elsewhere, then, build up their technologies to produce radical product innovation to compete in the market. Meanwhile, SS firms are continuously forced to develop and enhance their thechnology ability which will be able to support the improvement of production efficiency in customer sectors. Therefore, such kind of this nature might influence firms in SB and SS, to improve their NPD efficiency for being higher level. Nevertheless, eventhough previous studies have suggested that SI is regarded as low-innovation trajectories, it might not completely comform to Japanese manufacturing case. This may be explained by the advanced technology of Japanese automobile industry that is realized as a leader of the world. Thus, it might dominate SI firms in case of Japan for being higher innovative trajectory that results in no significant difference of development efficiency level comparing to SB and SS groups. From this point, the second hypothesis might be partially supported.

3.4 The relationships between development efficiency, financial performance and technology trajectories

In this research, the financial index of Return on Assets (ROA), from Japanese Nikkei NEEDS in the same year of NPDSC data, was selected. This index is often used to represent the firm financial performance in previous NPD studies [20], [21]. To verify hypothesis 3 and 4, the regression analyses by using dummy variable were carried out in this section. Three groups of supplier-dominated, science-based, and specialized suppliers were coded as the dummy variables of SD, SB, and SS, consecutively. Meanwhile, group of scale-intensive was omitted as a reference.

In the regression model, the financial index of ROA was set as a dependent variable. Then, the development efficiency performance, dummy variables of three groups, and interaction between dummy variables and development efficiency were taken up as the independent variables. The result of regression analyses was shown in the Table 8.

Table 8 Regression Analyses Result by using Dummy Variables

ROA as Dependent Variable, Standard regression coefficients displayed

Model	1	2	3
Developtment efficiency (Dev.Eff.)	0.162*	0.162*	-0.065
Supplier-Dominated (SD)		0.179*	0.068
Science-Based (SB)		0.273*	-0.516+
Specialized Suppliers (SS)		0.242*	-0.097
Dev.Eff x SD			0.075
Dev.Eff x SB			0.849*
Dev.Eff x SS			0.358
R2	0.026	0.068	0.112
△R2		0.042	0.044
Adj.R2	0.021	0.048	0.077
F	0.028*	0.046*	0.038*

Level of significant +=0.1, *=0.05

SD,SB,SS are dummy variables for Technology Trajectories category (omit Scale-Intensive (SI) as the reference)

From Table 8, model 1 is a baseline model which explores the main effect of development efficiency on the financial performance. The result shows that development efficiency positively impacts on ROA. It implies that when firms improve their development efficiency, their financial performance will be raised. This might be considered to support hypothesis 3. Then, the dummy variables of each group and their interactions with development efficiency were entered into the model 2 and 3, respectively. The results of model 2 and 3 showed that the R^2 increased significantly. Besides, the interaction terms of development efficiency and SB were significant with the highest standard regression coefficient. In this sense, it implies that when SB firms improve their NPD efficiency, they could significantly earn better ROA comparing to the other ones. As suggested by Pavitt [1], firms in this group usually generate the diversity of advanced technology which will consequently bring more product and market opportunities. Therefore, improving development efficiency might refer to effectively utilize these advantageous opportunities which might result in high potential of acquiring income from their new products and markets. This might be one reason to explain why improving NPD efficiency for SB firms could make higer contribution to financial performance than the rest ones. As a consequence, it might consider that hypothesis 4 is supported.

4 Conclusion

This study has explored the related aspects of NPD efficiency for Japanese manufacturing industry through the perspective of technology trajectories from Pavitt [1]. Four groups of industry were classified according to their sources of technology. They are supplier-dominated, scale-intensive, science-based, and specialized suppliers. The findings with implications are summarized as followings.

First, the exploration confirmed that technology trajectories affect on the determination of critical NPD operations for development efficiency. Firms in each group should focus on different critical operations in order to improve NPD efficiency. Firms in the groups which technology come from external related parties (supplier-dominated and specialized suppliers group) need the NPD operations that concern to external sources of technology in order to improve development efficiency. Since technologies for supplier-dominated group are provided by suppliers, firms in this group should specifically emphasize on the exchange of technical standardized data with their suppliers as well as the design rationale system. Meanwhile, because technology for specialized suppliers group are generated from customer requirements, thus firms in this group should put the importance on grasping needs of customers and markets and try to make the relationship with them to. On the other hand, to enhance NPD efficiency in the groups which mainly rely on internal development of technology (scale-intensive and science-based group), firms require the operations that are particularly conducted on their own. For scale-intensive group, firms should focus on product data management that will be able to respond their typical features of in-house technology development as well as their internal learning and experience. Meanwhile, firms in science-based group, which technologies are mostly generated from internal R&D, should especially emphasize on developing their human resources and organizations. Consequently, these results might be beneficial as the guidance for firms to know that based on their technology sources, which operations should be regraded as critical to constitute NPD efficiency.

Second, when comparing level of NPD efficiency among four groups, science-based and specialized suppliers group were significantly higher than supplier-dominated group. Besides, due to the advanced technology of Japanese automobile industry, it dominates scale-intensive group to possess higher development efficiency level than initial supposition. These results are not only reflect the existing level of NPD efficiency, but also refer to the necessity of this performance in each group. Focusing on the contribution to the business value, it is found that NPD efficiency positively associate with financial performance (herein, represented by ROA). In addition, improving NPD efficiency in science-based group could signficantly contribute to financial performance more than other ones. Firms in this group might take the advantage of building up NPD efficiency as an alternative to achieve their financial goal. Consequently, in line with the focusing on business value of development efficiency in science-based group, Hegde [22] supported that this group palys an important role in enhancing the innovation performance in the economic context.

However, this research just focuses on NPD efficiency aspect that directly relates to the technology factor, thus, there might be other NPD performance aspects (such as; quality and speed) beyond the scope of this research that would also need to compete in the market, as well. Finally, due to the merit of technology trajectories classification, this research could explore various view points of NPD efficiency not only for overall of Japanese manufcaturing industry, but also in the specific groups. In addition, starting from this research which employed technology trajectories concept to the scope in addition to UK and Europe, it might be attractive to further study in different innovation aspects in other countries.

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