Supply Chain Agility and Internal and External Process Connectivity: The Impact of Supply and Product Complexity

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Abstract- **The study attempts to analyze the impact of internal and external process connectivity on supply chain agility of manufacturing firms in Thailand. It also examines whether supply and product complexity moderates the impact of internal and external process connectivity on supply chain agility. The study relies on the questionnaire survey to collect the data. Using electronic survey, the respondents working in manager' positions in Thailand's manufacturing companies are targeted. Out of 250 survey questionnaires, only 173 responses were found usable with a rate of response of 57.2%. The study focuses on Thai firms because Thai manufacturing sector is one of the strongest players in the globe. The reason to select manufacturing firms is that the manufacturing firms are considered to be very crucial in global supply chains in terms of providing agility and responsiveness while delivering final products to the consumers. Supply chain agility (SCAG) is used as dependent while internal process connectivity (INPC) and external process connectivity (EXPC) are used as independent variables. Moreover, product complexity (PRCX) and supply complexity (SPCX) are used as moderating variables. Findings show that SPCX has negatively significant influence on SCAG while PRCX has insignificant effect on SCAG. INPC and EXPC have positive and significant impact on SCAG. The results state that both INPC and EXPC play vital role in attaining SCAG. The interaction effect of product term (INPC × EXPC) on SCAG is also found to be positively significant. These outcomes are in line with the process theory which states that both INPC and EXPC are significant factor that play important role in attaining SCAG. Both these processes permit companies to better respond to continuous variations.**

Keywords; *Supply Chain Agility, Internal Process Connectivity, External Process Connectivity, Product Complexity, Supply Complexity*

1. Introduction

The idea of agility firstly introduced in the literature of management in the beginning of 1990s and this concept was placed as supporting construct of stretchy system of manufacturing. About four year behind, [26] protracted this idea to the broader inventiveness quarreling that firms should become extra agile to flourish in the competitive environment of unpredictable and constant change. Scholars in operations management then pragmatic the ideologies of agility to manufacturing firms to advance the methodologies for the agile enterprises. Meanwhile, [27] also initiated the idea of "leagility"; this permits companies to assimilate lean and agile industrial standards in the operations of firms. Soon subsequently, researchers functionalized agility to supply chain; they argued that rivalry is no longer between the firms, but between the global supply chains that respond and adapt to changes in the environment of [28].

Supply Chain Agility (SCAG) signifies that how rapidly a chain of supply replies to changes in the environment, competitive forces and customer preferences, etc. SCAG does not talk regarding the random changes in executing daily supply chain (SC) operations. Instead, it specifies that how a firm's SC replies to variations. Once a business is getting aware of exterior variations which positively or negatively affects business in accomplishing its goals. SCAG is a measure about how firms adapt their SC to such variations and then how quickly it becomes able to attain it. SCAG comes with cost and occasionally this cost becomes massive enough to crack down the firm's profitability. Firms must have to decide "how much agile the business has to be and where in the value chain they need agility and whether it fits in well with overall strategy of the company". Identifying the variation in advance stretches lot of scope for the firms to reply to variations in the environment of business. Firms ambitious to be "Agile" must shape elastic organization and plan stretchy processes. Structure of the organization must encourage harmonization among different units or departments within similar partners as well as organization. Setting the targets for the lead-times and hence working for decreasing those lead-times particularly "Order to Fulfillment" lead-time will significantly help companies in order to attain the velocity that is required to be "Agile" in the current changing and competitive environment of business. Velocity, in how information develops over the SC and how quick the

tangible product travels down the SC, is a perilous feature in becoming a leader. The study attempts to fulfill the following objectives:

i. To analyze the impact of internal process connectivity (INPC) and external process connectivity (EXPX) on supply chain agility (SCAG) of manufacturing firms in Thailand.
ii. To examine whether supply complexity (SPCX) and product complexity (PRCX) moderates the association between INPC and SCAG and EXPC and SCAG of manufacturing firms in Thailand.

Life cycle theory helps in understanding the mechanism behind the development stages of products, organizations, and human beings. According to this theory, change is an integral part of any organization. An organization is developed according to an unseen rationality, which control the method of modification from an initial stage to a determined end. Organizations are born, then they make progress in numerous ways, and eventually, they demise. External processes can affect the maturity of any organization, but the progress of any organization is always facilitated by the integral rules. Processes reserve the organization maintaining its limitations. Similarly, these processes are the main reason behind the organizational collapse. Change do not only arise in organization but it also arises in different organizational entities, including individuals, team and across groups of firms. Supply chain is considered as a group of buyers, sellers and the organizational entities. Involvement of additional supply chain entities results change in that organization, where competition is between the supply chain, instead of companies. Supply change has to respond regularly for changing the events which results from the strategic decisions of the senior associates. However, for the efficient management of continuous change, supply chain requires constancy and agile process which permit quick response to the unforeseen actions.

We divided the remaining paper in the following divisions: next part reviews the prior researches on SCAG while fourth part of the paper is about the design or the research and methodology; in the fourth and fifth section the empirical findings and conclusions are provided.

2. Literature Review

2.1. INPC and SCAG

In numerous firms, different sectors and business units work in vault where the information is limited in separate managerial entities [1]. The managerial barriers, created by this compartmentalization interrupt in the exchange of knowledge and act as hurdle to the collaboration [2]. Those organizations are prosperous which impart vigorous communication between individuals and place a great value on interdepartmental cooperation [4]. Indeed, building intended associations between teams helps to diminish incoherence and reserve organizational direction (IBID). Therefore, connecting procedures between internal organizations agree for an initial and rapid exchange of information because the workers in particular departments use formal and informal links for considering the issues related to the projects [5]. For this purpose, IPC allows firm-wide detection of variations and more quick assessment of deviations with respect to definite internal restrictions i.e., production capacity [9]. Further, IPC allows a quick reaction to change by altering the product design, and by developing new products Connecting IPC expands the continuous flow of dealings through the firm which results less blockages. keeping these factors in mind, it is assumed that:

H_1: "INPC has a positive effect on SCAG"

2.2. EXPC and SCAG

Change procedures are hardly secluded with a separate organizational entity but happen across numerous entities instantaneously [12]. In this unified system, there is no such thing as marginal change [11]. Therefore, connected organizational entities requires the capability to react collectively to the disrupting events. [14] perceived the supply chain as a process which intensifies the requirement for external connectivity among the associates of supply chain. [16] developed a conjoint consideration of processes which enable the buyers and suppliers to recognize the complementarities, and enhance their aptitude to arrange the process for an active response. [23] indicated that the connected process allows the members of supply chain to share the data on the demand of clients [18] proposed that the connected process with the dealers can let the firm to regulate their delivery times, modify their inventories, and reduce destruction and mistakes through the enhanced flexibility of dealer. Further, more connectedness between the supply chain artists allow the realization of synchronized risk modification strategies. Thus, process connectivity allows the organizational entities to engage in supply chain, which is a key feature of SCAG. So, after reviewing the aforementioned literature, it is assumed that:

H_2: "EXPC has a positive effect on SCAG"

2.3. The Interactive Effect of INPC and EXPC

Internally connecting process significantly contributes in the exchange of information with the partners of supply chain, which in their turn permit the assessment of changes [22]. For instance, connected processes allows the buyers and suppliers to alter the production volume according to the demands of the customers [21]. Certainly, the capacity to harmonize supply and demand centers on the ability of an organization to link their internal and external functions with the dealers and clients [13].

Moreover, organizing the internal and external processes provides better understanding, regarding dependent influence of activities to the organizations which in their turn helps the organizations in the detention of their failures [3]. After considering the independent significance of internal and external processes connectivity, it is obvious that, these factors will improve the SCA collectively. Thus, it is proposed that

H_3: "The interaction of INPC and EXPC has positive effect on SCAG"

2.4. The Indirect Effects of SPCX and PRCX

Present study focused in the complexity of supply chain and indicated it as a key area of managerial concern [3]. It is an important factor which allows the effectiveness of supply chain process [25]. The complexity of supply chain is based on two main concepts i.e., product complexity and supply complexity. Both of the concepts provide the significant challenges to the managers when he is handling the change.

Existing literature has shown the significant influences of product complexity on the effectiveness of observes i.e., the development of common standards through the supply chain process [10]. Results showed the positive relationship between product complexity and the firm operations. It is concluded that firm has to face more difficulty in accessing their inputs with the increase in product complexity [6]. Further, product complexity tends to increase the vagueness and organizational challenges during the development and manufacturing phase of product [11]. Product complexity increase the probability of operational errors in predicting the requirements of raw material. The process of connectivity helps the firm to notice the failure more quickly [7]. Therefore, present study hypothesized that under the conditions of high product complexity, processes categorized by the common goals and a high degree of internal and external organization will allow the firm to provide an active response to change events:

H_4: "PRCX moderates the relationships between INPC and SCAG"

H_5: "PRCX positively moderates the relationships between EXPC and SCAG"

Supply complexity having significant effects on the effectiveness of internal and external method connectivity in permitting SCA, which includes continuous exchange of data with the dealers as they can efficiently respond to the demand [18]. Competitive success is a key factor of making the data accurate but the complexity of supply makes it difficult for the organization to expect and forecast the change. Unpredictable suppliers can seriously hinder the end to end led time of supply chain, which is serious in making a quick response to altering demand. Under the high complexity of supply, a firm faces higher operative load in the management of its supply base [24]. Connecting process enable active practices i.e., fast substitutions of resources or contingency planning, which are important in handling the supply disturbances. Further supply complexity is having positive influence on the effectiveness of variance reduction. Thus, we proposed that:

H_6: "SPCX positively moderates the relationships between INPC and SCAG"

H_7: "SPCX positively moderates the relationships between EXPC and SCAG"

2.5. Design of Research and Methodology

The study is based on theory testing (deductive) approach. In line with the prior researchers [17, 2] the study relies on the questionnaire survey to collect the data because the variables are latent constructs and are tough to observe. Using electronic survey, the respondents working in manager' positions in Thailand's manufacturing companies are targeted. The study focuses on Thai firms because Thai manufacturing sector is one of the strongest players in the globe. The reason to select manufacturing firms is that the manufacturing firms are considered to be very crucial in global supply chains (SC) in terms of providing agility and responsiveness while delivering final products to the consumers. Out of 250 survey questionnaires, only 173 responses were found usable with a rate of response of 57.2% (173 ÷ 250 ×100). 71.67% of the total participants were aged between 18-36 while the rest of the respondents were aged above 36. 19.07% of the total respondents were females while other 80.93% were male participants. 52.60%, 18.49% and 28.91% respondents had top, middle and lower level management positions, respectively. Moreover, the study is based on Likert type-5; SA (strongly agree) to SDA (strongly disagree).

2.6. Measures of Variables

Supply chain agility (SCAG) is used as dependent while internal process connectivity (INPC) and external process connectivity (EXPC) are used as independent variables. Moreover, product complexity (PRCX) and supply complexity (SPCX) are used as moderating variables.

Supply Chain Agility (SCAG): SCAG is measured following earlier researchers [8, 17]. The study measures SCAG as secondary construct which comprises of three sub-constructs; speed (SPD), flexibility (FLX) and sensing (SNS). SPD indicates a firm's ability to sharply respond to temporary and shorter-term changes in the environment of market and supply chain with present supply chain (for example, supply and demand and manufacturing), showing speediness in delivery times and/or set-up times [19, 29]. FLX is computed as the firm's ability to flexibly respond to temporary and shorter-term changes in the environment of market and supply chain with present

supply chain (such as, supply and demand and manufacturing). The items which represent FLX are delivery times, processes of production and throughput times [17]. SNS computes a firm's ability to sense temporary and shorter-term changes in the environment of market and supply chain by computing latent variable description towards the changes in the supply, demand, competition and technology [20].

Internal Process Connectivity (INPC): In line with the past researchers [5, 17], the measure of INPC is assessed on the basis of common goals, common standards, human skills and compatibility. For concern, in the questionnaire survey, the participants were asked to assess the extent to which; i. their company designates individuals with specific skills to direct several internal processes, ii. their company advances a mutual objective to bring into line the processes and customize particular goals for every process, iii. their companies confirm compatibility among all the relevant interior processes and iv. their company customs common standards for all interior processes to confirm all processes are connected smoothly.

External Process Connectivity (EXPC): This measure is also taken from the previous researchers [5, 17]. EXPC is related to the joint understanding, long-term alliance and coordination between suppliers and firm. Such as, the respondents were asked about how their firm alliances processes with its suppliers; whether all the suppliers have joint understanding with the processes of each other; and the extent to which processes between suppliers and firm shape towards long-term alliance.

Supply Complexity (SPCX): SPCX consists of the items which measures the number of a firm's direct suppliers, reliability of the base of supply, and presence of a higher market dynamism. This measure follows the following prior researchers [3, 17].

Product Complexity (PRCX): PRCX comprises of the items showing customization of the products and value-addition services, the number, product variants offering and components of product. The measure was taken from [22, 15].

2.7. Econometric Models

$$\mathrm{SCAG} = \alpha_0 + \alpha_1 \mathrm{SPCX} + \alpha_2 \mathrm{PRCX} + \varepsilon --- \text{Model (1)}$$

$$\mathrm{SCAG} = \beta_0 + \beta_1 \mathrm{SPCX} + \beta_2 \mathrm{PRCX} + \beta_3 \mathrm{INPC} + \beta_4 \mathrm{EXPC} + \varepsilon --- \text{Model (2)}$$

$$\mathrm{SCAG} = \gamma_0 + \gamma_1 \mathrm{SPCX} + \gamma_2 \mathrm{PRCX} + \gamma_3 \mathrm{INPC} + \gamma_4 \mathrm{EXPC} + \gamma_5 \mathrm{INPC} \times \mathrm{EXPC} + \gamma_6 \mathrm{INPC} \times \mathrm{PRCX} + \gamma_7 \mathrm{EXPC} \times \mathrm{PRCX} + \gamma_8 \mathrm{INPC} \times \mathrm{SPCX} + \gamma_9 \mathrm{EXPC} \times \mathrm{SPCX} + \varepsilon -- - \text{Model (3)}$$

Where; "SCAG is supply chain agility, SPCX is supply complexity, PRCX is product complexity, INPC is internal process connectivity, EXPC is external process connectivity, α_0, β_0 and γ_0 are intercept, $\alpha_1 --- \alpha_2, \beta_1 --- \beta_4$ and $\gamma_1 --- \gamma_9$ are coefficients and ε denotes error term."

3. Empirical Results

Table 1 shows measurement models' factor loadings. The factor loadings of all the constructs are provided in Table 1 and Figure 1. The loading value of SCAG1, SCAG2, SCAG3, SCAG4, SCAG5 and SCAG6 is 0.7961, 0.6974, 0.8943, 0.8124, 0.9134, 0.9074, respectively. The loading value of INPC1, INPC2, INPC3, INPC4 and INPC5 is 0.8964, 0.8079, 0.7931, 0.9517 and 0.7431, respectively. The value for EXPC1, EXPC2, EXPC3, EXPC4 and EXPC5 is 0.6980, 0.7128, 0.7089, 0.8270 and 0.7932, respectively. the loading value of SPCX1, SPCX2, SPCX3 and SPCX4 is 0.9237, 0.8927, 0.8867 and 0.8100, respectively. moreover, the factor loading value of PRCX1, PRCX2, PRCX3 and PRCX4 is 0.7492, 0.6971, 0.7001 and 0.9278, respectively.

Table 1. Measurement Model: Factor Loadings

Items	SCAG	INPC	EXPC	SPCX	PRCX
SCAG1	0.796	---	---	---	---
SCAG2	0.697	---	---	---	---
SCAG3	0.894	---	---	---	---
SCAG4	0.812	---	---	---	---
SCAG5	0.913	---	---	---	---
SCAG6	0.907	---	---	---	---
INPC1	---	0.896	---	---	---
INPC2	---	0.807	---	---	---
INPC3	---	0.793	---	---	---
INPC4	---	0.951	---	---	---
INPC5	---	0.743	---	---	---
EXPC1	---	---	0.698	---	---
EXPC2	---	---	0.712	---	---
EXPC3	---	---	0.708	---	---
EXPC4	---	---	0.827	---	---
EXPC5	---	---	0.793	---	---
SPCX1	---	---	---	0.923	---
SPCX2	---	---	---	0.892	---
SPCX3	---	---	---	0.886	---
SPCX4	---	---	---	0.810	---
PRCX1	---	---	---	---	0.749
PRCX2	---	---	---	---	0.697
PRCX3	---	---	---	---	0.700
PRCX4	---	---	---	---	0.927

Note: "SPCX is supply complexity, PRCX is product complexity, INPC is internal process connectivity, EXPC is external process connectivity"

Table 2. Descriptive Statistics, Reliability and Correlations

Items	SD	Mean	CA	CR	SCAG	INPC	EXPC	SPCX	PRCX
SCAG	2.9817	0.6931	0.7624	0.8961	**0.5974**				
INPC	3.6974	0.9731	0.8641	0.9314	0.3482	**0.5087**			
EXPC	3.0819	1.0671	0.8462	0.8187	0.2871	0.2087	**0.6187**		
SPCX	2.9909	1.3791	0.9134	0.9412	-0.3487	-0.1870	-0.0980	**0.6657**	
PRCX	3.9821	1.2974	0.7952	0.9004	0.1974	0.0874	0.0674	0.2228	**0.7098**

Note: "SD is standard Deviation, SPCX is supply complexity, PRCX is product complexity, INPC is internal process connectivity, EXPC is external process connectivity, CA is Cronbach's Alpha, CR is Composite Reliability; The square roots of the construct's AVE are provided along the diagonal values (given in bold). Off diagonal numbers are the Pearson correlation between the constructs".

Table 2 shows the descriptive measures, reliability and correlations of all the variables. The item's reliability was assessed through the test of "Cronbach's alpha (CA)". The measurement scales' validity was found significant with values of 0.7624 for SCAG, 0.8641 for INPC, 0.8462 for EXPC, 0.9134 for SPCX and 0.7952 for PRCX. Tolerable internal reliability CR measured ranged between 0.8187 and 0.9412 which is above or equal 0.7. Additionally, the study chanced the verge of convergent validity (AVE) of minimum 0.50; showing composite reliability (CR) is present in the data. The value of CR for SCAG is 0.8961, for INPC is 0.9314, for EXPC is 0.8187, for SPCX is 0.9412 and PRCX is 0.9004. moreover, the mean value (SD) of SCAG, INPC, EXPC, SPCX and PRCX is 0.6931, 0.9731, 1.0671, 1.3791 and 1.2974 (2.9817, 3.6974, 3.0819, 2.9909 and 3.9821). The values (other than bold) in the last five columns of Table 2 shows the correlation coefficients for all the study variables.

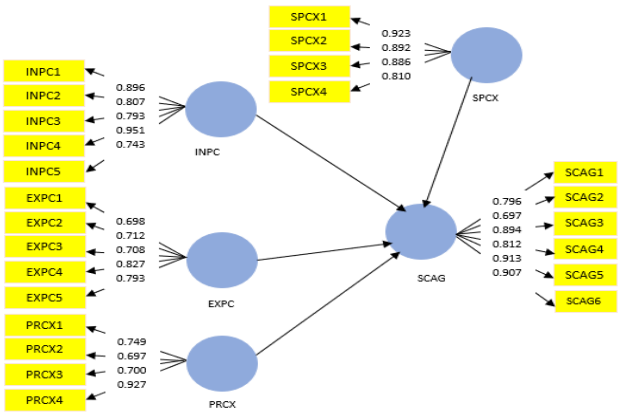

Figure 1. Measurement Model

Table 3 shows hierarchical regression outcomes (Also see Figure 2; Structural Model). The Table consists of three models. Model 1 comprises of moderating variables while in model 2 the direct effects of both the independent variables (INPC and EXPC) on dependent variable (SCAG) is tested. The study tests the interaction effects of INPC and EXPC on SCAG in Model 3. Model 1 shows that SPCX (-0.0975; 0.0000) has negatively significant influence on SCAG while PRCX (0.0864; 0.2541) has insignificant effect on SCAG. Model 2 of Table 3 indicates that INPC (0.1964; 0.0000) and EXPC (0.1765; 0.0000) have positive and significant impact on SCAG; supporting H_1 and H_2. The results state that both INPC and EXPC play a vital role in attaining SCAG. The interaction effect of product term (INPC × EXPC) on SCAG is also found to be positively significant. Here, H_3 is accepted. These outcomes are in line with the process theory which states that both INPC and EXPC are significant factor that play important role in attaining SCAG. Both these processes permit companies to better respond to continuous variations. The moderation of PRCX on the relationship between INPC and SCAG and EXPC and SCAG show insignificant impact and the moderation of SPCX on the relationship between INPC and SCAG and EXPC and SCAG also show insignificant impact. These outcomes indicate that $H_{4,5,6 \text{ and } 7}$ are not supported.

Table 3. Regression Analysis: SCAG

Variable	Model-1		Model-2		Model-3	
	α	Prob.	β	Prob.	ɣ	Prob.
Moderating Variables						
SPCX	-0.0975	0.0000 [a]	-0.0679	0.0246 [b]	-0.0564	0.0345 [b]
PRCX	0.0864	0.2541	0.0579	0.1764	0.0647	0.1467
Direct Effects						
INPC	---	---	0.1964	0.0000 [a]	0.2341	0.0000 [a]
EXPC	---	---	0.1765	0.0000 [a]	0.2299	0.0000 [a]
Interaction Effects						
INPC × EXPC	---	---	---	---	0.1864	0.0000 [a]
INPC × PRCX	---	---	---	---	0.0234	0.1468
EXPC × PRCX	---	---	---	---	0.0942	0.2546
INPC × SPCX	---	---	---	---	0.0451	0.2452
EXPC × SPCX	---	---	---	---	0.0427	0.2175
R^2	0.3845	---	0.4024	---	0.4412	---
Δ in R^2	---	---	0.0179	0.2148	0.0388	0.1874

Note: "[a] $p < 0.01$; [b] $p < 0.05$; SPCX is supply complexity, PRCX is product complexity, INPC is internal process connectivity, EXPC is external process connectivity"

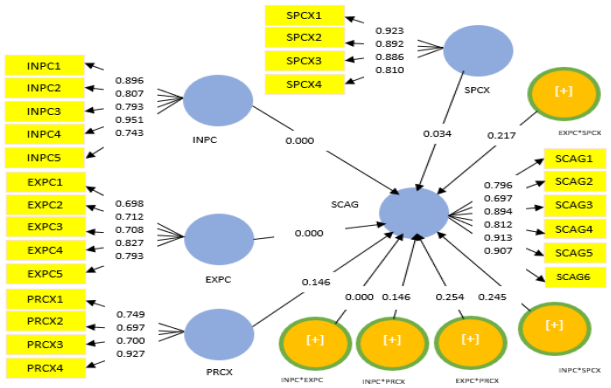

Figure 2. Structural Model

4. Conclusions

SCAG signifies that how rapidly a chain of supply replies to changes in the environment, competitive forces and customer preferences. SCAG does not talk regarding the random changes in executing daily supply chain (SC) operations. Instead, it specifies that how a firm's SC replies to variations. Once a business is getting aware of exterior variations which positively or negatively affects business in accomplishing its goals. SCAG is a measure about how firms adapt their SC to such variations and then how quickly it becomes able to attain it. SCAG comes with cost and occasionally this cost becomes massive enough to crack down the firm's profitability. Firms must have to decide "how much agile the business has to be and where in the value chain they need agility and whether it fits in well with overall strategy of the company". Identifying the variation in advance stretches lot of scope for the firms to reply to variations in the environment of business. Firms ambitious to be "Agile" must shape elastic organization and plan stretchy processes. The study attempts to fulfill the following objectives: i. to analyze the impact of internal and external process connectivity on supply chain agility of manufacturing firms in Thailand; ii. to examine whether supply and product complexity moderates the association between internal process connectivity and supply chain agility and external process connectivity and supply chain agility of manufacturing firms in Thailand. The study relies on the questionnaire survey to collect the data because the variables are latent constructs and are tough to observe. Using electronic survey, the respondents working in manager' positions in Thailand's manufacturing companies are targeted. The study focuses on Thai firms because Thai manufacturing sector is one of the strongest players in the globe. The reason to select manufacturing firms is that the manufacturing firms are considered to be very crucial in global supply chains (SC) in terms of providing agility and responsiveness while delivering final products to the consumers. Out of 250 survey questionnaires, only 173 responses were found usable with a rate of response of 57.2%. Supply chain agility (SCAG) is used as dependent while internal process connectivity (INPC) and external process connectivity (EXPC) are used as independent variables. Moreover, product complexity (PRCX) and supply complexity (SPCX) are used as moderating variables.

Findings show that SPCX has negatively significant influence on SCAG while PRCX has insignificant effect on SCAG. INPC and EXPC have positive and significant impact on SCAG; supporting H_1 and H_2. The results state that both INPC and EXPC play a vital role in attaining SCAG. The interaction effect of product term (INPC × EXPC) on SCAG is also found to be positively significant. Here, H_3 is accepted. These outcomes are in line with the process theory which states that both INPC and EXPC are significant factor that play important role in attaining SCAG. Both these processes permit companies to better respond to continuous variations. Moreover, the moderation of PRCX on the relationship between INPC

and SCAG and EXPC and SCAG show insignificant impact and the moderation of SPCX on the relationship between INPC and SCAG and EXPC and SCAG also show insignificant impact. These outcomes indicate that $H_{4,5,6 \text{ and } 7}$ are not supported.

The findings of this study report that INPC positively effects SCAG which helps companies to respond internally to the changes. It also helps firms about how they can become able to sense short-term variations in the rivalry' landscape and changes supply and demand. The findings also suggest that INPC, including the ability to ensure align processes and compatibility and to develop common objectives, positively influences a firm's ability to react to the change.

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