Impact of Process and Product Modularity on Competitive Performance of Thailand Manufacturing Firms: Mediating Role of Supply Chain Quality Integration

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Abstract---This study empirically investigates the relation between modularity and the impact it has on competitive performance of firms. It focuses on both the dimensions of modularity including process and product modularity. With the vast development of supply chain integration in firms, this study focuses on the quality management perspective of firms by assimilating supply chain integration system with it. Supply chain quality integration system has attained a significant attention over the world that allow firms to strategically collaborate its external and internal supply chain processes in order to obtain high level quality and competitive performance. Using survey method, this study construct a questionnaire to collect data from the manufacturing firms of Thailand. The data collected from those firms in the form of 304 respondents is analyzed by using statistical tools including SPSS and AMOS by running various tests such as descriptive statistics, reliability tests, CFA and SEM to identify the theoretical relationships between variables. The results of this study clearly depicts that both process and product modularity signifies a positive association with competitive performance of firms. It also signifies the mediation impact of supply chain quality integration between modularity and performance. It means that integrated supply chain practices enhance the development of better quality and innovative products. It also help firms in improving their set up processes by reducing costs and delivery timings to the end users that effectively influence competitive strategies.

Keywords: Modularity, process modularity, product modularity, supply chain quality integration, competitive performance, manufacturing firms, Thailand

1. Introduction

In today's competing world, firms are focusing more to attain an added value in order to provide more effective resources to their customers and suppliers by aiming and directing their attention towards those competences that have some core and direct relation with the firm value while subcontracting the other operations [1]. Supply chain integration has played a fundamental role in accessing the internal as well as external factors that help firms to recognize their abilities and to optimally utilize their available resources to achieve long lasting performance. It has also allowed firms to unite their all operations that are quite necessary for their supply chain processes [2, 3]. With the increase in production process worldwide, quality issues related to these supply chains have been under consideration [4]. Since these quality issues are directly related to the supply chain of manufacturing firms, therefore, attempts to increase practices in the form of bonuses, incentives or training etc. are not sufficient to control such issues [5]. Studies indicate that in response to quality management issues, firms have to move from traditional single business perspective towards a modern approach of supply chain perspective in order to enhance the qualities of their products, services and processes.

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The studies also indicate that by adopting supply chain quality perspective approach, firms will be able to effectively deal with their business processes with coordination and collaboration [6]. In order to obtain advantage from the customers as well as suppliers of a firm, it is necessary to provide more value added services and facilities to its customers by integrating its vast supply chain networks spread in the globally diversified world with the quality management processes of the firm [3, 4].

According to the author, supply chain quality integration is defined as the extent by which various business operations effectively and strategically cooperate and develop alliances with the external supply chain units in order to improve quality of their products, services and processes, to enhance inter business operations collectively, to properly communicate with the external markets and to achieve high levels of performance at relatively low costs using modules in their products and processes [6]. It involves three dimension mainly customer, supplier and internal integrations [7]. Literature related to supply chain integration clearly provide evidence that with collaborating suppliers and customers in internal quality processes improve the performance level of firms [7-9]. However, many findings fail to support this relation with the competitive performance [6]. Moreover, there is a lack of evidence in literature that provides sustainable methods to improve quality with mutually integrated quality system. Moreover, literature has given less attention to the modules related to the processes in a firm. So the purpose of this study is to deeply examine the significance of product and process modularity in the supply chain quality integration on the manufacturing firms of Thailand. It also provide answers to these questions that how process modularity and product modularity effect the competitive performance of firms, how significantly supply chain quality integration mediates between modularity and performance and how these quality integrated supply chains enhance firm competitive performance?

The hypotheses and framework related to this study is explained in next chapter followed by adopted techniques and methodology of the research. Moreover, the analysis of collected data using various statistical tools are also explained. Finally, the study is concluded on the basis of obtained results with some contributions, limitations, recommendations and future indications.

2. Literature review

Supply chain quality integration (SCQI) is considered to have a fundamental impact over the board by combining a firms' internal processes with the external ones. Internal processes involves functions related to quality, manufacturing, research and development, logistics etc. whereas external processes include all external partners related to supply chain which comprises of both upstream suppliers and downstream customers [10]. Although various studies try to focus on the influence of different function of supply chain integration (SCI) but very few have focused on it in terms of quality perspective. Therefore, this study focuses on both SCI and quality management and take into account SCQI as a major component in enhancing performance. SCQI is defined as the extent by which firms try to obtain higher quality performance levels by strategically collaborating its' both internal and external supply chain partners in order to improve its operations and to collectively manage inter along with intra relationships and processes. It also allow firms to improve their quality, communication processes at an entirely low cost [11]. Three main dimensions of SCQI includes supplier, internal and customer quality integrations. Among these, two dimensions which are supplier and customer integration are collectively falls under external quality integration which states the extent by which a firm integrates with its external partners in order to improve the quality processes of its internal strategies, policies and practices to meet the needs of end consumers [12]. Supplier quality integration focuses on quality matters related to suppliers and their coordination whereas customer quality integration is related to the increase in quality factors specifically linked with the critical customers [13]. However, internal quality integration deals with the firms' internal connections with the core quality competences and the extent by which a firm formulates its own strategies, policies and processes collectively to enhance customers' requirements. It comprises of cross functional relations between various units in order to emphasize on its quality management procedures and complexities [12].

Modularity which include both process and product modularity is defines as a graded structure which consist of numerous small components that are

prepared independently and that are aligned together to form a complete system [14-16]. Studies suggest that modules are small chunks that have a significant connections among themselves and also communicate with each other consistently through uniform interfaces [17]. Process modularity deals with the production processes whereas product modularity deals with the designing processes of a product [18]. Studies provide evidence that there is very limited literature available on process modularity than product modularity [19]. Modularity in processes or functions can be achieved only when the chunks of those processes are reconstruct with no or little loss [20]. Another study indicates that modular processes in a firm allows its functions to work autonomously [21]. And when these production units work independently, it is referred to as a module [22]. Process module is considered flexible as compared to product module because process modules can be activated or deactivated according to the need or demands of markets. Studies explained that with product modularity, firms enhances their product development and customization processes and reduces product related costs whereas process modularity speed up product development setup time, increase the profitability of lower volume production and reduce setup related costs. This increases the chances of performance growth of firms which allow them to attain advantage in the markets [19]. Thus, we hypothesize that;

H1: *There exist a significant positive association between process modularity and firms' competitive performance.*

H2: *There exist a significant positive association between product modularity and firms' competitive performance.*

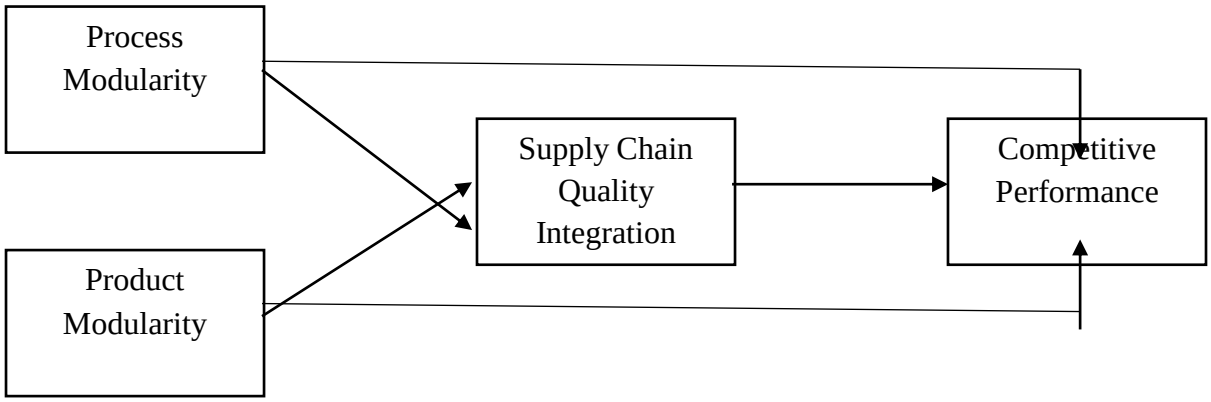

Figure 1: Framework of this study

Competitive performance is the ability of a firm to attain advantage in terms of its innovativeness or uniqueness. It is closely associated with the manufacturers' objectives to look upon quality, costs, delivery, innovation and flexibility all together [23]. Studies found a significant relation between upstream quality integrations with the performance [6, 24]. Supplier quality integration not only plays its role in enhancing quality and supplier's transparency but also emphasize on aligning the goals among suppliers and manufacturers by increasing competitive performance [25]. Studies depicts that close relations of a firm with its suppliers can enhance the quality of its products and services therefore reduces costs, errors, unreliability, wastage of time and late deliveries [11, 26]. Moreover, internal quality integrations allow functions to communicate laterally and make sound quality related decisions [5, 27]. It reduces the potential mistakes and confusions among units by improving internal transparency and processes [28]. Most importantly, it pushes every unit to take accountability of their decisions and processes that lower down the variations and costs associated [29]. Whereas, customer quality integration allows firms to focus deep into the needs of the end consumers in order to avoid design errors by producing reliable products [6, 24]. Direct contact with customers provides information about the specifications in their minds which allows firms to provide products in accordance with customer

expectations which reduces the level of uncertainties [4, 30]. Hence, on the basis of studies, proposed hypotheses of this study are;

H3: *Supply chain quality integration significantly mediates between process modularity and competitive performance.*

H4: *Supply chain quality integration significantly mediates between product modularity and competitive performance.*

4. Methodology

A survey was conducted in this study using questionnaires. The items or constructs for this scale are adopted on the basis of surveyed literature in order to identify valid measures for the variables under consideration [6, 23, 27, 31-33]. Then these constructs are modified and various items have been added or deleted according to the needs of present research. After this, the items have been reviewed carefully and attentively to avoid any error and pass through rigorous testing as well as revisions(Umrani, Mahmood & Ahmed, 2016). The medium of the questionnaire adopted is in English so that it can be relevant to the ongoing practices in Thailand and can be easily understood. Finally, the data collected is analyzed by running various tests using statistical tools such as SPSS and AMOS.

3. Data collection

The unit of analysis adopted in this study is the manufacturing firms that are primarily associated with supply chain integrations. All the manufacturing plants of the firms of Thailand are focused in this study. As these firms are highly associated with supply chain management, therefore, it was not allowed to do multiple responses. Firstly, the selected firms are contacted through mails and telephone. Some visits are been planned to the nearest firms that are in the reach of the researcher. Follow up from these manufacturing plants as well as visits are also planned on a continuous basis in order to collect data as soon as possible and to move further. Then in order to collect data completely and without any biasness, a person was appointed in these firms by their supervisors. Various managers including senior and middle level as well as supervisors that were closely associated with the issues related to quality of their products or services also filled the questionnaires. These include quality mangers, quality supervisors, inventory manger, plant managers, process engineering, plant superintendent, product development managers and supervisors. All of them were given proper time and filled the questionnaires with care. In these questionnaires, some that were not related to manufacturing unit were eliminated and those who were incomplete were also removed from the analysis leaving sample size to 304 questionnaires.

5. Measures

On the basis of extensive literature, the measures in this study are developed and adopted by the studies of [6, 23, 27, 31, 33] and went through series of psychometric and rigorous pilot tests. Those questionnaires who did not pass through these testings' are removed from the analysis. The questionnaires were prepared in English to avoid any ambiguity. Both Seven point and five point Likert scales are applied to measure the constructs of this study. The dependent variable in this study that is competitive performance is measured by using scale adapted from the research of Zhao, et al. [23]. For this, ten items are used to collect manufacturers' competitive performance data in terms of quality, flexibility, cost, distribution and innovation that makes them unique and novel as compared to other competitors in the market (Suryanto, Haseeb, & Hartani, 2018). To measure the performance, five point Likert scale is used ranging from 1 as 'poor' to 5 as 'superior'. In order to measure the independent variables adopted in this study that are product modularity and process modularity, seven point Likert scale is used ranging from 1 as 'strongly disagree' to 7 as 'strongly agree'. This scale is adapted from the study of Zhang, et al. [27] and Vickery, et al. [31]. Five items are used for both these independent variables in the survey in order to cover all the major aspects including interference, binding, standardization, common modules involved in the process of product design (Haseeb, Iqbal-Hussain, Ślusarczyk, Jermsittiparsert, 2019).

Moreover, in order to measure the mediating variable that is supply chain integration as a whole, three of its dimensions were considered and separate items were construct for each. These measures were adopted from the study of Huo, et al. [6]. To measure supplier quality integration, seven items were used covering all aspects on suppliers' communication, relationships, certifications and involvement of supplier in both design and quality of a product. To measure

internal quality integration, eight items were adopted covering all the internal relation and teamwork of the functional units and ability to solve any problem related to quality of products with coordination. Moreover, five items were used to collect information about Customer quality integration covering all the aspects related to customers' relationships, communications, cooperation, and presence of involvement in designing products and to maintain the quality by these customers. For all these dimensions of supply chain, seven point Likert scale ranging from 1 as 'strongly disagree' to 7 as 'strongly agree' were used to measure these constructs.

6. Data Analysis

In order to check the hypothesis status for this study, the collected data from 304 respondent was analyzed by using SPSS and AMOS, the results of demographical profile are the following;

Table 4.1: Demographic Profile

Characteristic	Category	Frequency	Percentage
Gender	Male	146	48.0
	Female	158	52.0
Age	Less than 20 years	21	6.9
	21-30 years	148	48.7
	31-40 years	64	21.1
	Above 41 years	71	23.4
Education	Graduation	107	35.2
	Master	100	32.9
	Other	97	31.9

Above mentioned table shows that, there are 146 male and 158 females were participate in this study. Mostly respondent falling in the range of 21-30 years of age and 107 respondents have graduation degree, 100 have master's degree and remaining have other degrees.

7. Reliability Test

The researcher used KMO and Kaiser-Meyer-Olkin (KMO) to measure reliability of data for factor analysis and then run Rotated Component Matrix. KMO returns values between 0 and 1. A **rule of thumb** for interpreting the statistic. The results of KMO test indicated our data is suitable for factor analysis and factor analysis also good fit. See table 4.2 and 4.3.

Table 4.2: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.965
Bartlett's Test of Sphericity	Approx. Chi-Square	21974.714
	Df	741
	Sig.	.000

Table 4.3: Rotated Component Matrix[a]

	Component			
	1	2	3	4
ProM1			.873	
ProM2			.862	
ProM3			.891	
ProM4			.830	
ProM5			.818	
ProM6			.851	
SCI1	.962			
SCI2	.957			
SCI3	.926			
SCI4	.924			
SCI5	.920			
SCI6	.930			
SCI7	.935			
SCI8	.939			
SCI9	.896			
SCI10	.840			
SCI11	.861			
SCI12	.794			
SCI13	.839			
SCI14	.859			
SCI15	.894			
SCI16	.872			
SCI17	.927			
SCI18	.921			
SCI19	.916			
SCI20	.913			
ProdM1				.906
ProdM2				.914
ProdM3				.917
CA1		.936		
CA2		.826		
CA3		.893		
CA4		.868		
CA5		.894		
CA6		.888		
CA7		.905		
CA8		.926		
CA9		.925		
CA10		.911		

7.1. Data Normality and Descriptive Statistics

Skewness is a test of the irregularity of the probability division of an actual valued random construct regarding its mean. Its value can either be positive or negative or indeterminate. Skewness

value ranges from "+1 to -1". This table also shows the descriptive statistics of the data;

Table 4.4: Data Normality and Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error
Process	304	1.00	4.00	2.7094	.96804	-.396	.140
SCI	304	1.00	5.00	2.9655	1.08744	-.373	.140
Product	304	1.00	5.00	3.4035	1.18828	-.431	.140
CA	304	1.00	5.00	3.3872	1.17653	-.557	.140
Valid N (listwise)	304						

Findings show that the skewness value for all variables is under the range from -1 to +1 that's why data is normal, and descriptive statistics shows that there is no outlier in the data.

7.2. Discriminant and Convergent Validity

Discriminant validity is the degree in which the variable is in fact differing from each other experimentally. On the other hand, Convergent validity is the extant of assurance a researcher has that a characteristic is well evaluated by its measures [34].

Table 4.5: Discriminant and Convergent Validity

	CR	**AVE**	**MSV**	**Process**	**SCI**	**CA**	**Product**
Process	0.961	0.805	0.279	**0.897**			
SCI	0.911	0.850	0.171	0.414	**0.922**		
CA	0.915	0.870	0.279	0.528	0.390	**0.933**	
Product	0.922	0.917	0.224	0.408	0.297	0.473	**0.918**

Results prove the convergent and discriminant validity of the data, because every contract discriminate from each other, and value of AVE for all variables are greater than MSV.

7.3. Confirmatory Factor Analysis

The confirmatory factor analysis (CFA) is "a multivariate arithmetic process which is utilized in order to examine how good the studied constructs signify the figure of variables." Following table shows the findings;

Table 4.5: Nested Confirmatory Factor Analysis

	Model Fit Indices	Threshold Range	Observed Values
Nested Model	χ^2		1593.782
	Df		696
	χ^2 / *df*	Lesser than 3	2.290
	GFI	≤ .80	.795
	IFI	≤ .90	.960
	CFI	≤ .90	.960
	RMSEA	≥ .08	.065

Above table shows the threshold range and observed value. The model above displayed the GFI=0.795; IFI=0.96; CFI=0.96 and RMSEA=.065. Above stated five indicators prove the CFA of the study except GFI, but it is near to range.

7.4. Structural Equation Modelling

By using AMOS structural equation modeling test was performed in order to test the hypothesis of this study, this test at the same time provide the direct and indirect results of regression;

Table 4.6: Structural Model Results

Effects	Hypothesized Path	B	S. E	P value	Conclusion
Linear Effects					
Hypothesis 1 (+)	Proc→ CA	.295	.065	.000	Accepted
Hypothesis 2 (+)	Prod→ CA	.303	.051	.000	Accepted
Mediation Effect					
Hypothesis 3 (+)	Proc→ SCI→ CA	.050	.022	.010	Accepted
Hypothesis 4 (+)	Prod→ SCI→ CA	.027	.013	.010	Accepted

Above mentioned table 4.6 shows the structural modeling results and finding indicated that process Modularity has 29.5% positive impact on competitive advantage, which mean that if one unit of process Modularity increased it will bring 29.5% positive impact on competitive advantage. Same as product Modularity has 13.3% positive and significant impact on competitive advantage. Hypothesis 3 and 4 shows the indirect effect of process and product Modularity on competitive advantage via supply chain integration. The finding of the hypothesis 3 indicated that supply chain integration has 5% mediating effect between process Modularity and competitive advantage whereas it has 2.7% mediating effect between product and competitive advantage.

Figure 2: Structural Equation Modeling

The following figure below is a screenshot of structural equation modeling while running in SEM in AMOS and shows the standardized regression weights between the variables

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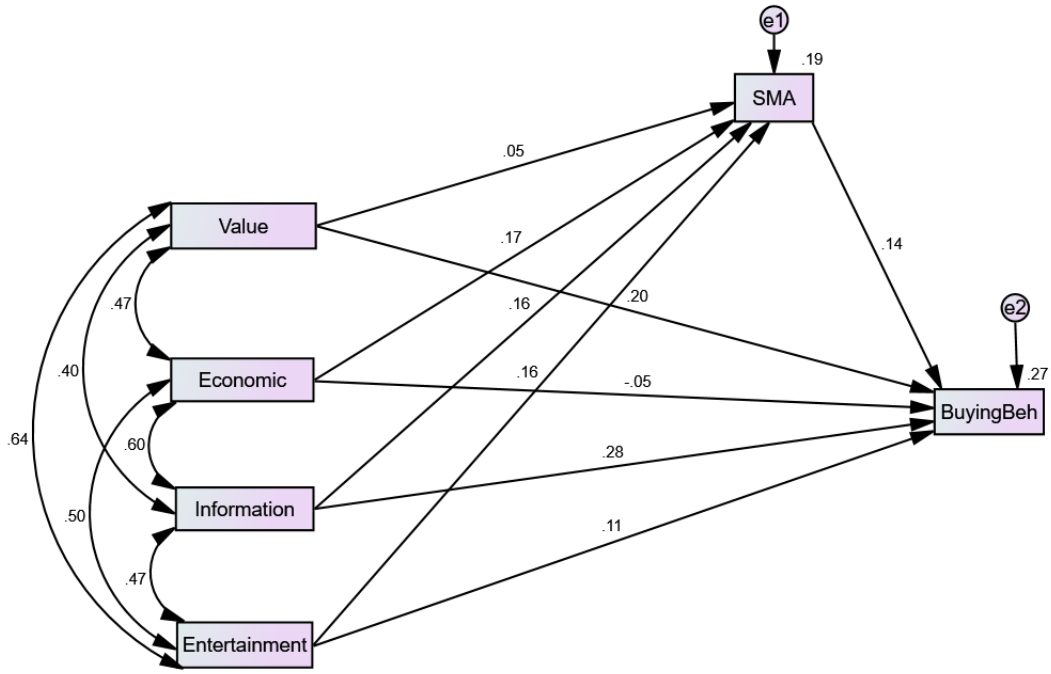

8. Discussion

Based on the analysis and results obtained in this research, it can be clearly seen that both the product and process modulatory have significant impact on the overall performance. These results were also in accordance obtained by past researches [35, 36]. Modular designs are playing fundamental role in the process of manufacturing components and to easily access quality of each and every component in process. It signifies manufacturing firms to procure separate components from their suppliers in the form of skids or modules to efficiently identify the problems associated with a certain component in coordination with the suppliers [35]. It allows firms to independently recombine these components by providing benefits to them in the form of flexibility, by providing creative solutions like augmentation and exclusion and by lowering down costs associated with customization and time. Both product and process modularity allows organizations to keep a balanced communication with the suppliers of their products in order to maintain the quality of their processes. It also establishes a one to one relation between firms and suppliers in designing and improving their products and processes according to the needs of their customers and external markets. Moreover, it also create emphasis on firms to solve potential conflicts including quality complications together by collaboration of internal systems and units [33]. Hence, on the basis of results, it can be stated that modularity directly affects the supplier quality integration.

As modularity deals effectively with the requirements of customers by modifying skids creatively and to identify potential defects in the whole manufacturing process, it also focuses on the firms' internal processes to work as a team to produce better quality producers according to the needs of its customers. It allows functional units to line up their goals thus increasing level of transparency among various units. Hence, modularity also affect the internal quality integration in some way as a result enhance performance level of firms. Furthermore, as the product of a company is directly related to its customer and the use or rejection of its products is directly associated with the customer, modularity allows firms to maintain a level of coordination between suppliers and its functional units to effectively deal with the increasing or decreasing demand of its customers. Studies emphasize on the connections between manufacturers and customers too to avoid major losses, quality problems and to lessen delivery times [6, 37]. The results of this study also evidently indicate that customer integration is positively associated with the performance levels. Hence, the overall findings of this research depicts that there exist a significant positive association between modularity and firm performance. Moreover, supply chain quality

integration and its three dimensions as a whole are found to have an influential impact on the competitive performance of manufacturing firms

Theoretically, this study is an addition in literature by focusing on the modularity function of firm including both product and process modularity on the competitive performance of manufacturing firms. It also signifies the importance of supply chain quality integration including suppliers, functional departments and customers as a whole and the effect of their coordination on quality improvements and performance levels. Practically, this study can provide help and allow mangers to effectively implement supply chain quality integration system among various functional units of the firm and to devise such policies that enhances their product quality by reducing the time and cost associated with processes. Managers must increase the transparency levels of their supply chains by adopting simple modular designs and processes. Moreover, in order to create synergy, firms have to develop learning skills to get knowledge from suppliers about market, implement it among functional units internally and thus producing competitive products in the market.

Although, this study has diverse contributions both theoretically and practically, but it has some limitations too that can be adopted in future studies. Firstly, this study focuses on the Thailand firms that makes it more in accordance to the perspective of Thailand. This study adopted cross sectional analysis therefore it lacks the longitudinal research to analyze the long term effects of supply chain integration on performance levels. Moreover, it has adopted variables that are left behind as a gap by various researchers [33, 38]. But there are many antecedents that affect the quality integration including government regulations, hostility or other modularity functions [6, 31, 33, 37]. Moreover, it has been seen that environmental or business factors influence supply chain integration as well [39], therefore, future studies can relate the effect of these factors on the integration chain.

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