The Supply Chain Integration, and Product Modularity as Antecedents of the Market Valuation of Firms in Thai Solar Industry

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***ABSTRACT*-The main purpose of the current study is to examine the supply chain integration, and product modularity as antecedents of the market valuation. The study is carried out on the supply chain of the solar industry of Thailand. The reason why the solar industry is chosen is that the greater emphasis on rising oil prices, global regulatory environment, and climate change resulted in increased adoption of clean technology processes. Over the next few decades, the solar energy would be considered as an important technology stemming from fast-paced innovation and huge technological investment. Being an infant industry, the solar energy supply chain is evolving rapidly with the entrance of new as well as already established firms. The study has used the SEM-PLS to analyses the data gathered from the firms in the solar industry. The findings of the study argue that the aggregated product modularity affects the supply chain flexibility and supply chain's ability of delivering product variety, across the supply chain. Such aggregated product modularity, being an important SC construct, shows the product modularity of supply chain as a whole.**

***Keywords*-** *Supply chain, Market value, Solar energy*

1. Background

In the past few decades, firms have shifted their emphasis towards value creation, particularly within the individual firms' boundaries to make collaborative efforts within the supply chain [1, 2]. Resultantly, effective supply chain and product integration are viewed as the sources to achieve competitive advantage by the firms [3-5, 38-40]. In fact, the organizations are identified in terms of their value-creation ability in supply chains. Such as, in a meeting with investors, the president of one of the leading groups has highlighted the potential value that can be added to the product and service supply chains. Although, so far, the truthfulness of their claim has not been assessed using systematic analysis. In terms of value-added supply chain capabilities, if the organizations are emphasizing toward product markets then they must also bring a superior SC performance in the capital market valuation. Although, it is an ambiguous practice to determine SC performance. Therefore, in order to create value and flexibility in a supply chain, firms may use multiple means to develop and arrange goods and services. Particularly, the modular design approach may be adopted independently or in collaboration with supply chain integration (SCI) [6]. This paper aims to examine the role of supply chain flexibility manifested by product modularity and integration, and quantification of their value particularly in the supply chains and product markets.

In addition, the flexibility theories were employed to propose the expected association among SC decisions taken by organizations and market valuation of these decisions. Empirically, the concept of flexibility is considered as an important measure to determine supply chain performance, with firms seeking for suppliers that are not only fast and flexible, but are low cost suppliers [2]. Capital market valuation process is one of the common measures to determine organizational performance, although this measure has not been used so far, to determine the end-to-end supply chain performance. [7] have attempted to examine the impact of supply chain disruptions on the valuation of stock market firms in the long run. Through an empirical investigation, they concluded that those individual firms which have faced supply chain disruptions exhibited lower stock returns i.e. 33-40% as compared to the benchmark level set by their industry for 3-years. [8] also analytically ascertained a firms' flexibility value through analyzing its network association with SC partners and overall SC capacity. However, there is a research gap existing in the SC performance, i.e. it does not directly measure the flexibility value of a supply chain using product modularity, network alliances, and integration. The solar energy sector is a growing sector as evident in the figure1.

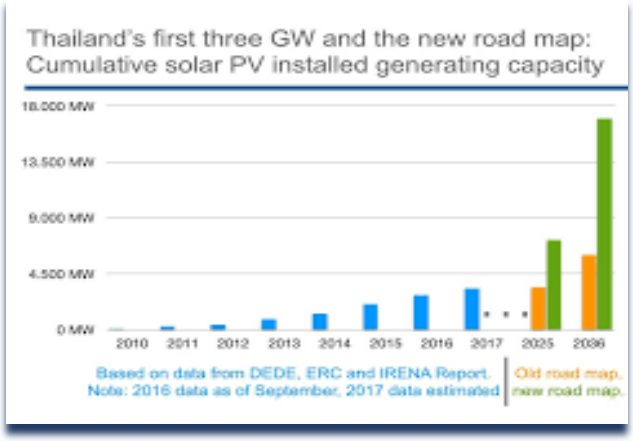

Figure 1: Thailand solar energy profile.

This study attempts to bridge this research gap in two ways: i.e. 1) it provides a theoretical framework which simplify relationship among supply chain valuation, SCI, and product modularity constructs; and 2) supply chain valuation is done by introducing a new measure which utilizes stock market valuations of individual organization to evenly take the aggregate of individual organizational performance in a SC. This method enables to analyze and test the proposed framework in this study, through analyzing 42 cases of unique supply chains and solar energy firms, for the year 2007. Consequently, it has been found that: 1) greater aggregate of product modularity brings higher SC value; 2) greater SCI is found to be related to higher SC value; 3) SCI and aggregate product modularity are related to SC value; and 4) the market valuation of partnering firms are affected by the SC network valuation.

2. Literature Review

2.1 Supply Chain Integration (SCI)

Supply chain refers to the interrelated value-adding activities ranging from the manufacturers to the suppliers and ultimately to the end users. Such activities involve controlling and planning of raw materials, constituents, and finished goods. Therefore, managers try to get a comprehensive view of SC activities and also strive to enhance supply chain performance through incorporating such activities for customer and supplier value-creation, thus, the higher the SCI, the greater will be the organizational performance [9]. However, each partnering firm is encountered with the network management which establishes interdependence and also demand SC coordination among the partners of supply chain. Thus, competitive advantage can be achieved by all SC firms through successful SCI.

The end-to-end supply chain flexibility can be improved through supply chain integration, by avoiding time delays among partnering organizations in a supply chain, i.e. in the goods and service delivery and in the upstream information transmission. A fully-integrated SC possibly acts as a single operating unit, i.e. in a supply chain, firms are vertically integrated which allow them to minimize product-related errors, exchange information, enhance quality, thereby improving the performance of overall supply chain [10]. Supply chain integration is a theoretical variable which is measured in terms of vertical integration (Section 4.2). Therefore, SCI improves the overall business operations and flexibility through minimizing the demand and supply uncertainties.

Superior SC flexibility brings cost savings, improved financial performance and customer responsiveness [2]. The literature on financial economics acknowledges that supply chain flexibility provide organizations the ability to reduce risk and manage uncertainty [11, 12]. Existing literature put forward that aggregated value for SC relationships and performance heavily depend upon the integration level.

2.2 Product Modularity's Value

Product modularity is classified into two complex processes, namely production of unique modules or components and hierarchical and decomposable design [13, 14]. According to researcher, modules are identified as the independent and interdependent across and within the SC boundaries, and combined together, in case if changes in one module may not influence or minimally influence other modules. [6] stated that it is possible to achieve new configurations without any loss of performance or system functionality. Such disconnection of modules take place by standardized interface adoption and by utilizing the components interchangeably, which enable the assembling and configuration of a various products [15]. Thus, modular products are adaptable and also provide flexibility to act in accordance to unexpected opportunities and threats, in case of shifts in the competitive environment [6]. Therefore, this organizational ability of rapidly redesigning modular products allows to offer product variety and satisfy the constantly changing and diversified customer demand, without any need to forecast product attributes and type to be preferred both in the short-term and long-term. In addition, organizations can grasp capabilities of their suppliers through outsourcing, instead of manufacturing on their own and in case of any uncertain conditions, it can also shift the production processes among their suppliers [16, 17].

Earlier researches have created a linkage among performance and product modularity. [6] have recognized product modularity value as a flexibility option. According to author, companies with higher product modularity may witness better product performance. Product modularity may reduce costs of production by realizing economies of scale, which emerges as a result of

multiple module applications, and reduced inventory and production volume [6].

While exhibiting product modularity, the process of standardization facilitates firms in achieving high quality, operational efficiencies by minimizing the coordination costs and low-cost repetitive manufacturing. In view of [18], a standard product component is comparatively less expensive as compared to components that are developed and designed for one particular product, since such components can be generated in greater quantity, thereby allowing shared learning and economies of scale [18]. This shared learning also allow firms to specialize in complementary products as well further reduction in costs of production. On the other hand, prior studies have shown that provision of product customization and greater product variety may result in increased component and manufacturing costs, in addition, the implementation of standards for consistent designs may also increase the costs of production.

Generally, firms adopt modularity while designing products, whereas, they also apply it in supply chain designing. The aggregated product modularity affects the supply chain flexibility and supply chain's ability of delivering product variety, across the SC. Such aggregated product modularity, being an important SC construct, shows the product modularity of supply chain as a whole. Similarly, decision-making by the supply chain members involve identifying compatibility standards, and observing mass customization strategies, leading to enhanced performance of supply chain [13, 19]. Resultantly, firms which use product modularity other than complementary customization and standards may also affect the overall SC performance value. Considering the ease of defection and possible increase in SC costs, capital markets try to reduce product modularity usage while determining the value of a SC [20]. Based on the varying benefits and cost impact of product modularity, the present study proposed a set of competing hypotheses regarding aggregated value of a supply chain and aggregated product modularity:

2.3 Product Modularity and Supply Chain Integration

The prior researches have examined the nature of association among level of product modularity, organizational performance, switching costs, and vertical inter-organizational relationships. Two different views have been suggested by scholars regarding product modularity and SCI relationship. The first group suggests that product design modularity reduces the integration for SC relationships, as these products minimize the need for controlling and coordinating through standardization process, thereby minimizing the inter-organizational dependence within the supply chain [6, 14]. Those suppliers which design and develop a product's modular component may save from customer uncertainty reduction and information, since alteration in one component design does not demand any variation in other components' associated with that particular design [15]. [21] have argued that product modularity provides flexibility and autonomy to the suppliers in order to establish multiple short-term SC relationships, for simultaneously selling modules to a number of customers. Due to low switching costs, suppliers of product modularity take no time to find new customers. Alternatively, the other group of scholars maintained that product design modularity give rise to the demand for concentrated supply chain relationships, which require joint customer-supplier investment, comprehensive efforts, and extended interaction time. According to [22], the product modularity suppliers are required to retain component-based knowledge access through intense SC relationships. These customer-supplier investments compel each supplier and constituent firm to procure similar organizational processes (such as, problem solving) and systems (computer-based designs) to benefit from their joint capabilities, within a supply chain [23]. [24] suggested that suppliers and customers should closely interact with each other for better coordination and communication in a SC, thereby improving the processes and products, enhance risk sharing and control of opportunism. It has been always been an area of discussion that what degree of SCI and product modularity may bring changes to the SC performance.

2.4 Value of a Supply Chain Network

Several researchers [25, 26] have attempted to examine firm value with respect to business diversification level, strategic groups and industrial sectors. However, investment in SC flexibility does not bring immediate benefits as it is a long-term decision-making process which can be observed in forward-looking market valuation. An increase in organizational value occurs as a result of a firm's ability of quickly and profitably responding to uncertain future events, through adopting operational flexibility [11, 12]. In view of [27], firms can receive certain SC advantages from the SC network and its access to suppliers' assets. Supply chain network valuation is estimated by using supply chain partnerships which are acquired through the coordination of multiple network organizations and also by using the organization's pooling capacity for quickly meeting the demand of its customers [8]. The SC linkages were recognized as crucial for organizations to achieve competitive advantage, however, firms generally ignore these linkages since they require scholarly understanding. According to Porter, goods and services obtain value through the product transformation process, i.e. delivering raw materials towards the end user and influence or get influenced by other SCs. Such linkages do not signify

transactions among firms, rather shows the dependency upon SC configuration to enhance customer-supplier benefits. [28] suggested that organizational boundaries and adding value to routine and resources can be bridged through critical resources. The SC value integrates the market valuation of all partnering firms and the supply chain value provided by each partnering firm. Therefore, the aggregated SC valuation acts as a SC construct, which considers the overall value of a supply chain. We hypothesize the following hypothesis, based on the above arguments.

Besides supply chain flexibility factors, which are assumed to be associated with SC and value of a firm, the current study considered key factors which were identified as firm valuation factors, in previous researches. Such as, the greater the profitability of firms the higher the chance for greater market capitalization [29], as compared to less profitable organizations. The revenue generation measure determines the performance and size of generated revenue and affects the value of shareholders [30]. According to [31], prior organizational performance also acts as a key factor in firms' valuation process. The current study hypothesizes that positive association exists among revenue, prior organizational performance, and profitability in a supply chain with the overall valuation of firm and the SC. In addition, rate of technological change also acts as a significant product modularity factor. Given the ever-changing market environment, firm must carry out additional investment-related calculation to assess the relevance of a certain module [5]. Thus, the intensity of research and development was included as a technological change factor. It is proposed that increase in of R & D intensity positively relates to the valuation of firm and SC. A close linkage exists among costs of production and integration level and product modularity usage, thereby reducing the costs of production and creating economies of scale throughout the SC.

2.5 Fixed Costs

The study administered production costs by adding a measure of costs of goods sold (COGS) and assumed that higher value of firm and supply chain relates to the lower production costs. In terms of supply chain design, fixed costs is the main consideration in the SC network [1]. Therefore, according to [32] firms may achieve competitive advantage by reducing the amount of fixed assets during uncertain and competitive market situations and by reducing the investment on fixed assets, which may also enhance the shareholder's value within the SC [30]. In addition, we hypothesized that there is a relation among higher SC valuation and lower aggregated fixed assets' proportion. However, the SC control appears to be the summation of firm-level variables in a particular SC in proportion with the weight of SC linkages (Section 3.3). Lastly, the product technological utilization is also considered. With a unique technology, SC functionality cannot be shared among other organizations. Thus, it is proposed that a relation exists among SC valuation and the type of technology employed.

2.6 Solar Energy Supply Chain

The hypotheses proposed in this study are tested by employing the financial data of public organizations for the year 2007, from the solar energy industry. Greater emphasis on rising oil prices, global regulatory environment, and climate change resulted in increased adoption of clean technology processes. Over the next few decades, the solar energy would be considered as an important technology stemming from fast-paced innovation and huge technological investment. Being an infant industry, the solar energy supply chain is evolving rapidly with the entrance of new as well as already established firms [33]. Moreover, in order to be powerful, a number of solar technologies have been competing with each other, such as, photovoltaic (PV) i.e. energy generation using crystalline cells or thin-film, and concentrated solar power using mirrors (NREL, 2011).

The present study gives greater emphasis to common photovoltaic energy generation because of its apparent network of supply chain. Different materials and technologies were employed by this research to develop thin-film in contrast to crystalline cells, where low cost PV solar energy modules are obtained through thin-film cells, however, these require more space and exhibit lower efficiency in generating power equal to crystalline silicon cells. The solar PV drivers involve, less waste during crystalline silicone wafers' processing, access to raw-materials, cost reduction by infusing technology-based efficiency for thin-film cells manufacturing, and vertical integration. Firms from solar PV industry are differentiated on the basis of their emphasis upon productive assets building and adoption of asset light strategies that are reinforced by multiple partnerships and proprietary technologies [34]. Therefore, the significance of technology, asset utilization, and integration of successful solar PV supply chain resembles the earlier identified theoretical factors, which are considered to be influential in the supply chain valuation. Furthermore, the solar PV firm's ability of acquiring materials and focusing upon SC partnerships indicate this networks' significance in the energy sector. In particular, solar PV industry functions as a global SC having its production and installation in Asia, North America, and Europe.

3. Measurements and Methods

3.1 Supply Chain value

In order to determine supply chain value, the firm's market value is aggregated using the earlier discussed

method, (Section 3.3). For this purpose, market capitalization is employed as a measure to determine the market value of a firm, where market capitalization is equal to the closing share price x common share outstanding for a particular financial year. This is a simple method as compared to an advanced Tobin's q.

3.2 Independent Variables

Using the references made by all 42 firms in the annual reports of 2007, the data is compiled for the product customization, standards, and product modularity. However, the content analysis for gaining information has been presented and discussed in Section 3.5. Besides, a vertical integration measure is also used for the smooth functioning of SCI. For investors, vertical integration is considered to be a most straight-forward mean for analyzing firm's level of integration throughout all the four SC processes.

A scale is formulated with a range of 1-4, on the basis of individual firm's ability of delivering adjoined processes within a SC. A score 4 is given to a supply chain, if it comprises of one vertically integrated organization holding all the four SC processes. Such as, REC in Figure 3 is assigned with a value of 4 since it delivers all four supply chain processes. However, a firm with three adjoining SC processes is assigned with score 3. Similarly, a firm that possess two adjoined SC processes gets a score of 2, whereas, score 1 is assigned to a chain having four distinct firms within a supply chain.

3.3 Network Design

Network design of a supply chain assumed as an essential input in our analysis, as mentioned earlier. However, [35] have stated that a SC network is generally assessed using a certain percentage of firm's valuation and a set of dependent measures observed by a specific SC. With a purpose of explaining all end-to-end supply chains, the market share of materials for every possible SC position is identified. Afterwards, for each particular SC link, we identified the material proportion for that particular position, which is transferred among all organizations which are directly associated to a supply chain.

3.4 Controllers

The current study used profit margin to control profitability, where profit margin refers to the ratio of operating profit and the revenue. However, revenue is estimated as annual generated revenue for the financial year 2007, in addition, revenue also regulates the size and the performance of an organization. Prior organizational performance is also considered to use the market capitalization value obtained during the financial year 2018. Furthermore, production cost is estimated using a ratio of total costs for goods sold by total revenue. R&D intensity refers to a ratio of R&D expenses to the revenue. R&D intensity level is used as a proxy to obtain the technology innovation rate. On the other hand, the fixed-asset intensity is defined as the proportion of all assets employed to make long-term investments by a firm, such as physical plant, equipment, and property. It is generally measured using by dividing fixed assets to the total assets. As mentioned earlier, the data for this study is obtained at firm-level

and was added afterwards through algorithm of all 42 SCs. In this study, technology is taken as a dummy variable i.e. whether a thin-film energy cells or silicon-based energy cells are produced by the supply chain.

$$\boldsymbol{FSCV_{it}} = a_0 + a_1 lnFPM_{it} + a_2 lnSCIN_{it} + a_3 lnFSCS_{it} + a_4 lnFSCC_{it} + a_5 lnFR_{it} + a_6 lnFOM_{it} + a_7 lnR\&DI_{it} + a_4 lnCGS_{it} + \epsilon_{it} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where,

FSCV: Firm's supply chain value
FPM: Firm product modularity
SCIN: Supply chain integration
FSCS: Firm supply chain standardization
FSCC: Firm supply chain customization
FR: Firm's revenue
FOM: Firm's operating margin
R&DI: R&D intensity
CGS: Cost of goods sold

4. Results

The panel data methodology is adopted for achieving the research objectives (Hidthiir et al., 2019). The OLS, Fixed effect are employed the agonistic tests have provided support to fixed effect estimate.

Table 1. Results of the Diagnostic test

Model	Statistics	Breusch and pagan test/ autocorrelation test	White Heterosced asticity test	Hausman test
1	Prob>chi2 Prob>z	0.0000	0.0000**	0.0053**

Assessing the collinearity issue is the first step while analyzing the structural model. Collinearity is the degree of high correlation among the two model indicators. Table … shows that result of collinearity test is indicating that all variables have satisfied the threshold level i.e. tolerance level came out as greater than 0.20, and the value for VIF <5, thus confirmed the absence of multicollinearity in the model. The VIF value falls within 0.243-0.439, and tolerance level lies within 2.278-4.122.

The results of the pooled OLS and the fixed effect estimate are shown in the table 2 below.

Table 2. The impact of CRDR and LIQDR on the OBSA

	OLS	Fixed Effect
FPM	0.4310**	0.5090***
SCIN	0.3503*	0.4213***
FSCS	0.3981*	0.4081***
FSCC	0.1300*	0.4321**
FR	0.6210	0.4901***
FOM	0.7021**	0.8901**
R&DI	0.3001*	0.7821*
CGS	0.6321*	0.0829***

The results of the study have provided support to the hypothesis results. In our analysis, it is observed that aggregated product modularity together with SCI tend to be positively associated to higher SC value, on the other hand, reduced R&DI intensity is found to be associated to higher SC value. Hence, there exist a trade-off between SCI, product modularity, delivery cost and storage and production, thereby influencing the value of a solar energy supply chain. Thus, a key issue in this regard is assessing the limits and effects of standards and modularity to enable supply chain coordination. In a study, [36], explained the market value for introducing a new product. Although, their assessment prevents the occurrence of any tradeoffs. The results of this study indicate that it has been recognized by stock markets that there is also a cost associated with the use of SCI and product modularity. Thus, product modularity combined with SCI is an ideal way to use product modularity as it may bring benefit of reduced costs of production.

5. Conclusion

The findings of this study suggest that higher SC valuation is associated with greater SCI. In fact, it is found that SCI can bring 28 percent increase in supply chain value, thereby validating the findings of [9], and is also consistent with the empirical findings. The supply chain integration (SCI) measure estimates the total number of SC position which can be held by an organization, therefore, the more vertically integrated a firm is the more chances of it to be positively related to valuation. A global organization having its presence in all solar supply chain positions and obtained around 1.5 billion dollars as a result of being vertically integrated and due to its expected market value. However, such tradeoffs are somehow different as compared to the traditional strategies for profit

	VIF
FSCV	2.617
FPM	2.927
SCIN	3.265
FSCS	2.994
FSCC	3.366
FR	2.698
FOM	1.915
R&DI	2.781
CGS	3.762

maximization, assuming that integration of network effects and product modularity can increase the total revenue of a firm [6]. According to [37], value maximization models, regarding production and supply chain must analyze these tradeoffs. Therefore, this is taken as an opportunity to re-examine the model.

The findings of this study offer operational insights for the policy makers. However, regulatory bodies, i.e. Energy (ARPA-E) and the U.S., the Advanced Research Projects Agency, and the Department of Energy support certain energy-based technologies by policymaking and investing in these technologies. Thus, assessing powerful policy alternatives considers to be an effective path to initiate follow-up work. A clear portrayal of data and solar technologies at various vertical integration degrees, make this industry a suitable sector for testing of hypotheses. However, studies which are based on other sectors, i.e. bio-tech manufacturing or photonics having clear distinction of their SC roles and flexibility measures, may also explain the market value creation and innovation position. Thus, in order to maintain SC feasibility and to avoid industrial effects, this study is confined to only one sector i.e. energy sector.

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