A LITERATURE REVIEW ON EMPIRICAL STUDIES IN SUPPLY CHAIN FLEXIBILITY

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Abstract: The supply chain flexibility (SCF) describes the ability of a supply chain to quickly and economically deal with the uncertainties in business environments. Supply chains strive to be flexible and this need arises due to increased pressure on organisations to respond to growing global competition. The importance of flexibility has been long known to supply chain managers and now it is becoming a central issue in supply chain management. However, the methods and terminology used among researchers and practitioners differ, leading to incoherent theories. This paper surveys the recent empirical research in the SCF literature and its antecedents, precisely, manufacturing flexibility and agility. This paper helps to assimilate the key knowledge about relevant practices in SCF and to understand, conceive and implement SCF within and across organizations. The paper concludes with the research gaps and suggested future research directions.

Keywords: Supply Chain, Supply Chain Flexibility, Dimensions of Supply Chain, Flexibility sources, Flexibility Drivers, Attaining Flexibility

1. Introduction

Since 80s, there has been a significant amount of research work in manufacturing flexibility (e.g. Slack 1983, 1988, Sethi and Sethi 1990, Koste et al., 1999, 2004; Chang et al. 2006). The literature on manufacturing flexibility merely considers physical resources, for example, flexible manufacturing systems, as the method to deliver flexibility (Jaikumar, 1986). Today’s the markets are customer driven. Customers demand more variety, better and reliable quality, tight delivery dates and services at much faster rates. Manufacturing flexibility being internal in nature to a firm is not sufficient to deal with an uncertain and turbulent environment, as modern firms are connected through very complex supply chains (SC) and operate in a much risky environments (Prater et al., 2001; Narasimhan and Das, 2000; Jack and Raturi, 2002). To overcome the above said difficulties, firms need to develop flexibility at various levels from intra organisation to inter organisation supply chains. Now, it is important to look ahead i.e. from the flexible factory to the flexible supply chain (Krajewski et al., 2005; Schmenner and Tatikonda, 2005; Slack, 2005). In order to be successful, firms must elevate flexibility from an operational perspective to strategic cross organizational perspective ( Duclos et al., 2003). SCF follows a logical extension of manufacturing system flexibility (Lummus et al., 2003).

2. Supply Chain Flexibility

Gunasekaran et al. (2004) view SC flexibility as a way of providing options to the customers. Garavelli (2003) defines flexibility as a hedge against the diversity of the environment. Supply chain flexibility as defined by Das and Abdel-Malek (2003) is the robustness of the buyer-supplier relationship under changing supply conditions A highly flexible relationship is one in which there is little deterioration in the
procurement price under different supply conditions. Flexibility is very complex and a multi-dimensional concept, which is difficult to summarize and hard to attain. (Sethi and Sethi 1990, Upton 1994, Wadhwa et al. 2008, More and Babu 2009). Lee (2004) described the flexible ability of a company in terms of three distinctive components, Adaptability, Alignment and Agility. Adaptability help to adjust the supply chain’s design to meet structural changes in markets, modify supply network designs and strategies, Alignment helps to create incentives among the participating agents within the supply chain. Agility is the ability of a supply chain to respond to short-term changes in demand or supply quickly and handle external disruptions smoothly. However the much cited definition on manufacturing flexibility by Upton (1994) states that ‘flexibility is the ability of a firm to change with little penalty in time, effort, cost or performance’. This definition focuses on range, mobility and uniformity of different set of alternatives available which provide flexibility in the system. Upton’s (1995) further argued that flexibility is enacted as a response to different types of problems and there are usually multiple responses to the same set of problems. Koste and Malhotra (1999, 2004) used Upton’s study to further explore and provide a meta-framework to develop conceptual model for SCF. More and Babu (2007) presented a new definition of flexibility as “the inherent ability, or characteristics of the SC and its partners to be sensitive to the minor or major disturbances in business environment, assess correctly the real situation, respond quickly by the way of adjustments and adaptation with little time, effort and cost and control effectively the organization with stable performance.” There is still no general agreement on how to define flexibility More and Babu (2011). Flexibility may, however, appropriately be redefined as following.

“A SC is said to be flexible if it can ensure smooth undisrupted supply of the products from supplier to the end user under all uncertain or risky environments, with the least variation in the difference between the demand and supply at every node, and without much penalty or impact on the SC resources and the costs incurred.”

Risks and uncertainties may arise from a number of situations e.g. demand is one of the largest sources of variability which is responsible for bull-whip effect. Firms can choose a variety of strategies to react to demands for flexibility; they can reflect back those demands, they can adapt those demands, they can absorb them internally or transmit them to other parties (Easton and Araujo, 1997).

3. Dimensions of Flexibility

Flexibility is a multi dimensional concept and various authors have perceived it according to their research problems. Different names have been used for the same dimensions. Flexibility dimensions are not mutually exclusive since some of them may overlap partially. Various authors have defined these dimensions separately. Shewchuk et al. (1998) found a set of 80 flexibility dimensions in their literature review.

Table 1: Dimensions of flexibility

<table>
<thead>
<tr>
<th>Authors</th>
<th>Number of dimensions of flexibility</th>
<th>Dimensions of flexibility</th>
</tr>
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<tbody>
<tr>
<td>Slack (1988)</td>
<td>5</td>
<td>Product, Volume, Delivery, Mix, Quality.</td>
</tr>
<tr>
<td>Sethi and Sethi (1990)</td>
<td>11</td>
<td>Machine, material handling, operation, process, production, routing, volume, expansion, program, production, market.</td>
</tr>
<tr>
<td>Vickery et al. (1999)</td>
<td>5</td>
<td>Product, Volume, Launch, Access, Responsiveness to market(s)</td>
</tr>
</tbody>
</table>
More and Babu (2008) has tabulated a total of 37 definition from literature. More and Babu (2011) considered flexibility in 36 dimensions and established contextual relationships among each pair. The flexibility types have been classified based on hierarchical relationships and also based on their power of influence and degree of vulnerability. This helped obtain better insight about the influential relationships of the flexibility types in the SC. Some of the dimensions of flexibility in manufacturing and supply chain as described in the literature are as tabulated in Table 1.

<table>
<thead>
<tr>
<th>Narasimhan and Das (2000)</th>
<th>10</th>
<th>Equipment, Material, Routing, Material handling, Program, Mix, Volume, Modification, New product, Market/delivery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Garavelli (2003)</td>
<td>2</td>
<td>Process, Logistics</td>
</tr>
</tbody>
</table>

4. Perspectives of flexibility

a) Supply Chain Flexibility from a tactical and strategic point

From a strategic point flexible manufacturing, flexible logistics, flexible information system and flexibility in supply system is required. A flexible manufacturing system can respond to changes in the external environment by quickly producing good quality products to meet customer needs. It includes machine flexibility, product flexibility, process flexibility, run flexibility, expansion flexibility and production flexibility.

b) Supply Chain Flexibility from a business management point

From the business management viewpoint, sourcing and product development, effective and efficient organizational design, strategic decision making and healthy corporate culture building in business also require the appropriate degree of flexibility. R & D flexibility ensures ability of firm to quickly develop different types of new products and new or better technology and introduce it to the customer and launch it into the market at lower prices. It enables to capture the market opportunities.

c) Supply Chain Flexibility from a ‘cooperation’ point

Every individual department of an organization aims to be the best department in the organization. Each division/department applies its own strategy to achieve it. In doing so, the organizational goal do not remains aligned with individual divisions and its effectiveness loses its focus. Therefore cooperation is required not only in the intra firm division but also among various entities participating in a supply chain. Good partnership is a must to improve the resource allocation and to quickly re-configure resources at minimal cost and hence it helps to improve resource flexibility. Better resource flexibility enhances the competitiveness of the entire supply chain. Next the distribution of the benefits, may be in terms of revenue, needs to be flexible.

5. Drivers of flexibility

In volatile and uncertain business environment as that of today’s, the supply chains are compelled to look for the various alternatives in demand and supply processes to maximize their revenues. A typical supply chain consists of three levels, the supplier, the focal firm and the buyer. Researchers and practitioners found not just manufacturing flexibility but the SCF to cope against such risky and turbulent environment (Prater et al., 2001, Ratauri et al. 2002). Drivers of flexibility are factors or situations that creates the need for flexibility (Pujawan, 2004). In this section we focus on various drivers and sources of supply chain flexibility. (Ratauri et al, 2002; Duclos et al., 2003). More and Babu (2008) identified three major dynamic forces to realise required flexibility and diminish
vulnerability of SCs. These are stimuli, enablers and inhibitors. Table 1 summarizes the drivers of flexibility and the sources from where to attain it at different levels of supply chain.

Table 2: Drivers and sources of flexibility.

<table>
<thead>
<tr>
<th>Drivers of flexibility</th>
<th>Position in supply chain</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal Driver</td>
<td>Manufacturing</td>
<td>System Control, Co-ordination, Material handling, Labor, Machine Purchasing, Process, Operation etc.</td>
</tr>
<tr>
<td>External Driver</td>
<td>Upstream (Supplier)</td>
<td>Unresponsive, Unreliable supplier, volume and mix flex available from supplier, Delivery uncertainty, Single supplier dependence, Risks and disruptions</td>
</tr>
<tr>
<td></td>
<td>Downstream (Buyer)</td>
<td>Demand uncertainty (Volatility, Seasonality, Forecasting errors)</td>
</tr>
<tr>
<td></td>
<td>Logistics (Inbound/Outbound)</td>
<td>Lead Time uncertainty, Delivery uncertainty etc.</td>
</tr>
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6. Studies and Models on SCF: A review

The literature in SCF can be categorised into

i. Conceptual models
ii. Empirical studies
iii. Simulation models/System modeling
iv. Analytical/Mathematical models

In this paper, literature review based on empirical studies is only being taken up.

Mark Stevenson et al. (2009) explored the empirical study in flexibility in an inter-firm context, by trying to provide answer to their research question ‘What specific inter-firm practices are used to achieve increased flexibility in buyer-supplier pairs and in the wider supply chain or network, and how do these practices and effects interact?’ They selected 16 firms from three different industries and conducted 20 interviews on few core themes such as collaborative relationships, information sharing etc. Ten different aspects of flexibility were found based on empirical evidences. These are collaboration, product design, supplier qualification and training, sourcing policies, information sharing, shared resources, inventory policy, tactical outsourcing, leasing and hiring and standardisation & codification. These aspects were directly linked to trade-off between configuration flexibility and planning & control flexibility which is said to be responsible for supply chain performance. They claimed their research paper to be the first to discuss inter-connected supply chain from network perspective. However like most of the empirical studies it also suffers from certain drawbacks. It assumes similar characteristics of inter-connected firms which rarely are observed in real world. Also, the results can’t be extended and accepted for different industries. There are many other authors who have carried out empirical studies to identify attributes of SCF or to analyse relationship between various attributes. Few empirical papers are available on the particular subject of supply chain flexibility (Vickery et al. 1999; Garavelli, 2003). In these papers the various dimensions of supply chain flexibility analysed are usually associated to manufacturing systems e.g. Vickery et al. (1999) identified the relationship between production flexibility and the financial performance of the firm. They found five different SCF types and their empirical study showed the effect of these dimensions on many business performance measures such as Return on Investment (ROI) etc. Jack and Raturi (2002) identified sources of Volume Flexibility (VF) in long term and short term in a firm and showed their effect on financial performance of the business. These sources were related to the slack capacity, inventory buffer, seasonal labour, flexible shift and SCM practices etc. Few other authors have developed some conceptual models of supply chain flexibility. For example, Duclos et al. (2003) and Lummus et al. (2003) examine flexibility classification schemes and the commonalities of flexibility typologies to create a theoretical foundation for analysing the components of SC flexibility and identify the cross-enterprise nature of supply chain flexibility to improve flexibility measures across firms.
Following the work of Duclos et al. (2003) and Vickery et al. (1999), Sanchez and Parez (2005) developed a framework of supply chain flexibility dimensions with a combination of process flexibility (similar to manufacturing flexibility, discussed much in the literature) and logistics flexibility (not included in manufacturing flexibility and rare in literature). Their study was concentrated on Spanish automotive industry suppliers. 126 useful questionnaires were received with a response rate of 35.4 percent. They developed four hypotheses based on following ideas. The first hypothesis concerns the relationship between supply chain flexibility and firm performance. The second was based on reduction of risk perception that may diminish the need for flexible capabilities. They also hypothesized degree of technological complexity that may also influence the company’s need for flexibility and the final hypothesis on the reduction of the number of suppliers and the development of suppliers within the automotive companies to increase and diversify the flexibility dimensions in the supply chain. Based on mean performance rating of flexibility dimensions, they statistically showed that the most rated flexibility was delivery flexibility, followed by volume flexibility and routing flexibility. The least important dimensions are launch flexibility and sourcing flexibility. Further their results also indicate that not every flexibility dimension is equally related to every firm performance measure. As a consequence, logistic and production managers should plan the effects of each flexibility dimension to highlight the outperforming dimensions for the company’s competitive advantage. It is therefore advantageous to tailor a flexibility strategy precisely to the characteristics of a given supply chain. Sanchez and Perez (2005) discussed the relationship among the dimensions of SCF, the firm performance and the effect of environmental uncertainty. Chang et al. (2006) explored the relationship between supplier involvement, manufacturing flexibility and business performance in the motherboard industry and further carried out a field study to benchmark various supplier involvement practices. Balram et al. (2007) examined the relationships between supplier and plant flexibility to profitability and growth in the process inventory. Skipper et al. (2009) conducted a study to examine relationship between planning process and flexibility and to determine the attributes of planning process that are highly related to flexibility. A web-based survey was used to collect data from 400 respondents most of whom were senior official, top notch managers and process planners of various industries. A multiple regression result proved that a top management support, resource alignment, information technology usage and external collaboration provide largest contribution to flexibility. Flexibility aids to the generating value among participating firms of supply chain. Soon and Udin (2011) suggested relationship between supply chain capabilities and value chain flexibility (VCF) by conducting an empirical research based on case study of four multinational companies. Some of the recent studies on flexibility are particular industry specific e.g. Candace et. al. (2011) performed a multi case study by analysing five textile firms of China. To counter against uncertainties of the firms focussed for this study, they found out four flexibility strategies helpful, namely, laggard, conservative, agile and aggressive. This study remains very specific to just one industry, textile. Daniel et al. (2011) focused their study in service industry to analyse the relationship between operational flexibility and outsourcing benefits in a field based empirical study. They concluded that there is a positive influence of operational strategy on outsourcing benefits. Gosling et al. (2012) developed and investigated a four step framework for achieving appropriate flexibilities to mitigate uncertainties in supply chains. The study was done on two construction supply chain network that include 12 suppliers. The four steps framework was to classify the supply chain, to identify and analyse uncertainties, to optimise pipelines and to develop strategic flexibility. The empirical study provided a structured approach which consolidates and establishes relationships between fields and concepts. Sparrow (2012) conducted 47 interviews with international mobility directors of various sectors to infer that these managers use three strategies to manage local responsiveness. Flexibility strategy is used in
international mobility as an environmental demand or pulls force via a three stage flexibility model. Yu et.al. (2012) conducted a multiple case study to analyse distribution flexibility in four Chinese manufacturers from different industries. They showed that under given circumstances, firms might choose an appropriate distribution flexibility strategy which fits with their distribution environment in the contingency theory sense of matching.

**Limitations of Empirical studies**

Limited generalisation of results is a major drawback of most of the empirical studies is that the results obtained, cannot be generalised. An empirical study is done on a firm or a group of firms considering situations pertaining to those firms so the results may not be consistent when this study is extrapolated to other industries. The other major drawback lies in the collection of data. The respondents provide answer to the queries according to how they perceive the question. It becomes more difficult if a structured questionnaire based or web based survey is done. The data thus collected, itself, might not be reliable. Semi-structured interviews are however a better option. While responding to a question on flexibility, a respondent might misinterpret multi dimensionality of flexibility concept and the interaction or dependence among various dimensions. An extensive theoretical and conceptual understanding of flexibility as per requirements of the research should be established and conveyed to the respondents. The empirical studies in the literature are mostly confined to a single firm level and revolve around manufacturing flexibility. There is lack of understanding of what factors to take into account to justify strategies for improving flexibility of SC. An inter-organisation empirical study considering the entire supply chain is quite rare. Moreover, empirical studies on flexibility are criticised for failure to capture a multi-facet inter related dimensions of flexibility; qualitative factors such as role of services in inter-firm operations, relations among various entities of supply chain; not able to encompass all the industries with few set of rules on flexibility; incapable of answering crude question on quantitative aspects of flexibility e.g. how much of flexibility. Data collected at a single point of time do not capture the dynamics of the demand supply mechanism. Table provides an insight on some empirical studies on flexibility and key findings.

7. **SCF: An approach**

Acquiring SCF is not a binary function. One cannot claim of its SC to be not flexible one day and flexible the other day. Being flexible is a continuous and gradual process.

**Agility and SCF**

Lee (2004) explained flexibility in terms of 3A’s Agility, Alignment and Adaptability. He defined agility as the capacity of a SC to handle or respond quickly to any changes in demand/ supply or external disruptions in short term.

In relation to flexibility, agility is viewed in different perspectives by various authors, some of which are as follows.

- flexibility is a subset of agility (Lummus et al., 2003)
- agility is a foundation for understanding flexibility (Lummus et al., 2003)
- flexibility is an antecedent to agility (Swafford et al., 2006)
- agility is an important feature and an extension of flexibility (Kara et al., 2002)
- flexibility focuses on the ability to change while agility focuses on rapid response through reduced reaction time (Swafford et al., 2006)
- agility is a capability, and flexibility, a competency (Swafford et al., 2006a) Lin et al.
- agility is not only based on responsiveness and flexibility but also on the cost and quality of goods and service (Gunasekaran et al., 2008).

Lin et al. (2006) further described Agile supply chains (ASC) to be the ones which focuses and flexibility
and adaptability. The four main capability of agile supply chain, they found, were

1) Responsiveness: ability to detect changes and follow up quickly,
2) Competency: Ability of firms and SC to realize its goals effectively,
3) Adaptability: To integrate various activities, processes, functions, equipments and labor to achieve desired results and
4) Speed: To bring about the required changes as quickly as possible.

In the words of More and Babu (2008)
‘The boundary between flexibility and agility is fuzzy and naturally obscured and therefore, it is very difficult to distinguish agility and flexibility concepts as both are still evolving concepts. Flexibility is the ability of organisations to adapt to internal and external environmental changes, while agility is associated with speed as well’

Flexibility and Adaptable

Chan and Chan (2010) and Corinna (2012) demonstrated with the help of their industrial case studies, that a quick and speedy adaptability to the environmental uncertainties makes a supply chain more flexible. Das Malek (2003) have advocated a policy of maintaining supplier pool and to select suppliers according to needs and convenience in order to enhance procurement flexibility

Information sharing is willingness of firms to share tactical and strategic data with its partnering firms and is considered to be one of the most important aspects of supply chain flexibility. It is now established that better information sharing with partnering firms improves flexibility and responsiveness of the supply chain (Gosain et al. 2005; Stevenson and Spring, 2007; Ogulin et al.2012).  

Postponement techniques in SCs are inculcated by being flexible in logistics and structure to counter demand uncertainties. Postponement is holding the base materials and sub assemblies until actual order from end-user is realized and then quickly transform/assemble/customize these items to finished good and delivers it at the earliest. (Prater et al. 2001; Duclos et al. 2003; Christopher et al. 2011).

8. SCF and Various Tradeoffs

1) Flexibility and efficiency
Adler (1999) clearly reported tradeoff between flexibility and efficiency as they stated,

….. [Organisations theory] argues that efficiency requires bureaucracy, that bureaucracy impedes flexibility, and that organisations therefore confront tradeoffs between efficiency and flexibility….

Their empirical study on mitigation of efficiency-flexibility tradeoff at Toyota subsidiary.

2) Flexibility and cost
Sometimes cost and time parameters are used to capture efficiency Duclos et al. (2003), Garavelli (2003), Nair (2005), Aprile et al. (2005, 2006) and Hindo (2007). Rafay, (2012), therefore, observed it indirectly bears similar tradeoff with flexibility as there is between efficiency and flexibility.

Some more tradeoffs have been sparsely discussed in the literature like, flexibility and speed; flexibility and risk; flexibility and uncertainty, flexibility and responsiveness, flexibility and controllability etc but More and Babu (2008) observed that the recent trend however is to consider cumulative models for competitive priorities than empirical study based tradeoffs.

9. Research Gaps and directions for future research

Some potential research directions that evolved during the course of writing this review paper are as below

- Defining and Classifying flexibility requires further investigation. It is still an evolving concept with vague terms and definitions, most of the time which
are context specific. There are hardly any précised or coherent definitions.

- Studies related to dynamic forces of SCF such as stimuli, enablers and inhibitors are rarely addressed. There is a need of thorough empirical researches and analytical modeling, in such areas which have tremendous potential to create an understanding of the flexibility in global SC and its implementation.

- Evaluating SC flexibility is a major challenge. In a multi level SC, it becomes difficult to measure SCF since there may not be common activities/processes at each firm level of SC and therefore practice of flexibility may be in different forms. It is very difficult to get a suitable unit of measurement applicable to each individual partner of SC and for various dimensions of flexibility. Focus is needed in this field.

- Operationalisation of flexibility in practicality may be a complex and tedious job since it requires introduction and awareness of flexibility to each individual of SC related to it and therefore a proper flexibility communication is required. In absence of above two points, it becomes even more difficult.

- Some degree of flexibility can be obtained by maintaining inventory buffers but there may be an interesting cause to get flexibility in inventory itself. There is no work done in this dimension of flexibility which has a great potential to counterbalance/mitigate the effects of major risks of plant disruptions and high degree of uncertainties.

- Some empirical studies have tried to explore relation between various dimensions of flexibility and their impact on SC performance. However, there are still a number of dimensional aspects of flexibility not touched and their interrelationships are not vividly explored. A huge amount of empirical research waits to avail better insight of dynamics and interdependencies of dimensions of SCF.

- There cannot be ‘a set of rules’ to in cult flexibility in SCs of different industries but for a same/similar industry, research can be focused to find some thumb of rule which can provide SC, the inherent flexibility in that particular industry.

SCF is no free lunch and it may require huge investments to realize its potential benefits. ‘How much flexibility is required’, thus becomes the core concern for firms willing to be flexible. This question is rarely discussed in the literature and therefore measuring SCF is a prominent field where research needs to be focused.

10. Conclusion

Changes are inevitable in uncertain business environments of today’s volatile supply chains. There are organisations which strive to manage this uncertainty while there are others which do not. The concept of flexibility originates from this need to mitigate the ill-effects of uncertainty and therefore, a need to incorporate flexibility has drawn attention of researchers and practitioners worldwide, for more than two decades now. Since flexibility is a complex and multidimensional term, no general agreement is found on its definition and dimensions. In this paper, after a rigorous study, an effort is made to redefine SCF, its perspectives, enablers, sources and various tradeoffs. In literature, a large number of empirical studies have been conducted through cross-sectional or cross-industry interviews, electronic surveys or postal questionnaires. Most of these studies remain at the firm level and not for overall supply chain. This paper also presents a literature review on the empirical studies done in this area and encapsulates various methods, approaches and strategies, firms and SCs use to be flexible. Finally, a number of research gaps are identified for fellow scholars and practitioners to focus, design and conduct their researches to find operational policies for overall supply chain benefits.

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