March-April 2020
ISSN: 0193-4120 Page No. 5970 - 5977

Exploring the Parameters of Agility & Resilience in Food Supply Chain

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Article Info
Volume 83
Page Number: 5970 - 5977
Publication Issue:
March - April 2020

Article History
Article Received*: 24 July 2019*
Revised*: 12 September 2019*
Accepted*: 15 February 2020*
Publication*: 01 April 2020*

***Abstract*:**

Agility and Resilience are the two most talked concepts of handling supply chain risk management. Agility is unexpected and ad hoc alteration to any unforeseen events which are happening at a particular time. It also means the ability to quickly respond to the unpredictable changes which can occur in the supply chain. Resilience is defined as ability to survive despite the weathering changes which can occur for any events of risk at any time in the supply chain. There are several of approaches which discusses means tomeasure supply chain performance correlated to discreet variables like agility and resilience. In our approach to this paper, we have arrived at mathematical regression model using Augmented Dickey Fuller Model under assumption that supply chain is a discreet time series function and it follows a stochastic process. The paper discusses the approach to arrive at weightage factor using a curve-fitting technique for the independent variables effecting agility and resilience. In the mathematical construct using a non-linear regression analysis technique,the weightage factors are studied over the standard Likert's scale of 0-10. This relative scalar measurement provides input to the curve-fit to arrive at weights to the regression model. The weights of each of the independent variables are considered in the stationary time-dependent regression model to understand the delta of the measured variables, in our case agility and resilience.

Keywords: *Operational Performance Index, Supply Chain, Agility, Resilience, Food Supply Chain*

I. Introduction

Distinct competitiveness in an organisation requires organisation capabilities. Organisations acquire distinct and sustainable competitive advantage through their supply chain capabilities. Hence it is necessary for organisations to have methods or frameworks to model supply chain with current scenarios pertaining to the firm. Functions and characteristics of supply chain keeps on changing with time and necessities. Agility and resilience are the two time based discreet variables which are

Published by: The Mattingley Publishing Co., Inc.

March-April 2020
ISSN: 0193-4120 Page No. 5970 - 5977

perceived as per laws of economics. Agility is the ability to respond to any disruption in the chain while resilience is defined as the capacity for an enterprise to survive, adapt, and grow in the face of turbulent changes in an organisation. The challenge in the present scenario is about quantifying the intangibles like agility and resilience for the supply chain performance for any firm.

Agility is termed as the capability of supply chain that encompasses of logistics, organisational structure, perspectives of respondents and information systems (Katayama & Bennett, 1999).In order to drive the concept of 'agility' it is important to be responsive to the needs of the dynamic competition, changing needs of the customer and increasing level of turbulence due to disruption in the supply chain system. Christopher (2000) makes a clear distinction between speed (meeting the customer demand in terms of shortened delivery lead times), leanness (doing more with less) and agility (responding quickly to the changing demands in terms of volume and variety). The perception of agility has reached beyond the traditional boundaries of the organisation. It is considered to bring about a holistic approach to measure the performance of the organisation since it will include all the levels of organisation at functional, strategic or tactical level (Power, Sohal & Rahman, 2001).

Resilience in supply chain is a concept which is very new and emerging. It is important for an organisation to withstand any changes which would occur in the system. Resilience is defined as "the ability of the substance to retain to its original state after deformation"(Cranfield School of Management, 2003). Resilience of the supply chain comes into picture for example, if there is an outbreak of virus and the firm is responsible to manage the pharma and medic supplies or managing supplies for floods in the country. Such kind of disruption can be managed with proper planning and implementation. The agile and resilient concept does influence supply chain competitiveness and performance. These two approaches will contribute to more competitive supply chains in terms of time to market, quality and customer service, thereby improving market share and reinforcing leadership. The paper aims to study the variables which can impact the agility and resilience of the supply chain. Based on the parameters identified, model fitting is carried out for to finalise the weighted factors which would be considered in the final model for measuring agility and resilience performance as the key variables. The proposed model considers the econometric approach based on Augmented Dickey Fuller regression modelling for the measurement approach for agility and resilience in the food supply chain.

II. Literature Review

Higher customer service rate at lowest possible cost is one of the major goals of supply chain management. So as to achieve this and to have better profits, the firm must minimise cost and maximise benefits along the supply chain **(Luthra et al,2013).** Decisions are to be made after having efficient cost vs benefit analysis. Hence supply chain management have major focus on customer service. Integration of supply chain and other operational factors enables the organisation to have all functions involved in management decision **(Cuthbertson, and Piotrowicz, 2011).** The major objective of supply chain is to "provide right material at right time to the right stakeholders, in the right quantity and right condition to the right place and right cost and right time." Considering the variability in the nature of customer necessities at different time function, supply chain faces multiple dimensions of challenges correlating to managing the performance of the supply chain function. **(Carvalho, Azevedo & Machado, 2012).**There are various changes which goes in the ecosystem of the business. **Azevedo, Machado, Barroso & Cruz (2008)** points out the following changes:

- Customer service to relationship management
- Adversarial relationship to collaborative relationships
- Forecasting to end casting
- Functional integration to process integration
- Vertical to virtual integration and
- Information sharing among the stakeholders in supply chain

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There are various quantitative and qualitative models developed so far for measuring performance of supply chain. A model that considers organisational functional level of the performance of supply chain with performance metrics being considered in the empirical modelling is agility and resilience of the supply chain.**Baramichai, Zimmers and Marangos (2007)** considers that ‘‘an agile supply chain is an integration of business partners to enable new competencies in order to respond to rapidly changing and increasingly fragmented markets’’. This means that supply chain competencies has to be improved so as to respond fast to the changes in the business. **Carvalho, Azevedo & Machado (2012)** clustered agile approaches in three levels within the supply chain:

- Agile practices developed upstream (interactions with firms and suppliers)
- Practices deployed by firms in their day to day internal operations
- Agile practices deployed downstream (between firms and its downstream partners in delivery activity)

Resilient supply chain is sometimes associated with organisation capability to spend for the infrastructure or team. It is also relating for an organisation to be more capable to confront any difficult situations for future and early preparation or investment for the cause may help the organisation in future. A resilient supply chain always cannot be a low cost and vice-versa. **Hames (2006)** discusses the dual aim of resilient supply chain is to recover to the desired state of the system which is disturbed within stipulated time and acceptable cost and to reduce the impact of disturbance by changing the effectiveness level of the potential threat. **Carpenter et al. (2001)** examined the magnitude of disturbance that a system can tolerate before it fundamentally changes into a different region with a different set of controls. The concept of resilience was expanded by introducing adaptive cycle notion. According to this theory, dynamic systems do not tend towards stability or tend to achieve equilibrium. It rather evolves through four stages viz. rapid growth and exploitation, conservation, creative destruction, and renewal or reorganization-adapting to disturbances. **Timmerman (1981)** discusses that resilience has three primary properties. Firstly, the amount of change that a system can undergo while retaining the same controls on structure and function. Secondly, the degree to which the system can organize itself without disorganization or force from external factors. Thirdly, the degree to which a system develops the capacity to learn and adapt in response to disturbances. Resilience of a society is the measure of its capacity to absorb and recover from hazardous events and its occurrences **(Timmerman, 1981).**

Timmerman (1981) was one of the first to define resilience of a society as the measureof a system’s capacity to absorb and recover from the occurrence of a hazardous event.Psychological aspect has its roots in developmental theory that deals with theexamination of people’s behaviour across the life span and encompasses anunderstanding of biopsychological factors as well as the spiritual realm **(Conrad,1999).Reich (2006)**discusses fundamental principles of resilience based on psychology which occurs as a result of human-made or natural disasters:

- Control (coordination of activities, direction and regulatory affairs).
- Coherence (processes and procedures needed to reduce uncertainty, enhancing meaning, direction and understanding during the worst times).
- Connectedness (behaviour to bend together; systematic coordination of efforts toavoid duplication and wastefulness of services).

Resilience can be distinguished into two (**Ross, 2004**):

- Inherent - Ability under normal circumstances (e.g. the ability of markets to reallocate resources in response to price

Published by: The Mattingley Publishing Co., Inc.

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ISSN: 0193-4120 Page No. 5970 - 5977

signals or the ability to substitute otherinputs for those damaged by an external shock).

- Adaptive - Ability in crisis circumstances due to innovation or extra effort (e.g.increasing input substitution possibilities in individual business operationsorstrengthening the market by providing information to match suppliers withcustomers).

The levels at which resilience can take place are microeconomic(individual); meso-economic (sector, market, or cooperative group); and macroeconomic(all individual units and markets combined). These levels mirror the social systemperspective and are applicable at the firm and supply chain level**(Ross, 2004).**

Resilience has been defined in terms of adjustment to capacities or abilities in organisational perspective. It is the capacity to adjust and maintain desirable functions under challenging orstraining conditions **(Weick et al., 1999; Bunderson and Sutcliffe, 2002;Edmondson, 1999)**, it is a dynamic capacity of organizational adaptability that grows and develops overtime **(Wildavsky, 1988)**; and the ability to bounce back from disruptive events or hardship **(Sutcliffe andVogus, 2003**).**The adaptive capability of the supply chain to prepare for unexpected events, respond todisruptions, and recover from them by maintaining continuity of operations at the desiredlevel of connectedness and control over structure and function.**

1. Research Methodology

1.1 Problem Statement:

"There are several models of agility and resilience discussed in various qualitative framework, but the models do not provide a unique measurement approach to quantify the variables in the time-series attributes of measuring performance in the supply chain which leads to ambiguity in establishing the measurement approach to quantify the qualitative variables which forms the intrinsic part of any supply chain performance attribute."

1.2 Research Design:

The research is a conceptual research which focus on arriving at an innovative mechanism for the measurement of agility and resilience, which is a intrinsic measure of the supply chain. It correlates the supply chain to the econometric time-series function and helps to arrive at the measurement approach.

Model is developed based on the literature about the performance measurement metric for intrinsic measures of supply chain. The design can be explained in the below framework shown in figure-1 below:

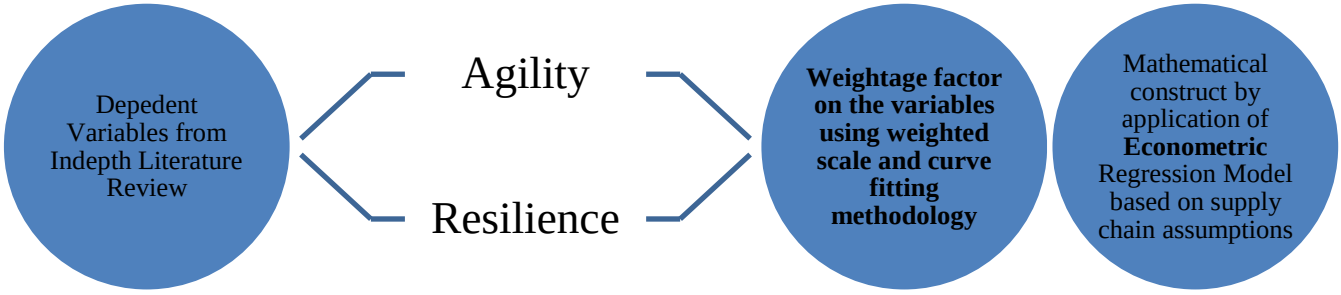

Figure – 1: Research methodology

1.3 Weighted Scale and Curve fitting:

Lin et.al (2006) discusses that due to ambiguous and imprecise criteria for the evaluation of the indicator variables (agility and resilience), it is difficult to quantify the performance on a continuous measurement. Hence, considering the nature and

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March-April 2020
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characteristics of the indicator variables, a linguistic scale type of reference is considered.

2. Proposed Model

2.1 Curve fitting for the multipliers and weightage:

The weighted factor calculations are based on the table as indicated below:

Weightage	Indicators	Multipliers
0-2	Low	0.5
3-5	Medium	1.5
5-7	High	3
8-10	Very High	5

The weighted factor is put into a curve fitting model which will suggest the best parameter estimates which best fits the model.

Model Summary and Parameter Estimates

Dependent Variable: multipliers

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.909	89.862	1	9	.000	-.205	.532		
Logarithmic[a]	.	.	.	.	.	.	.		
Inverse[b]	.	.	.	.	.	.	.		
Quadratic	.935	57.271	2	8	.000	.276	.211	.032	
Cubic	.949	43.818	3	7	.000	.601	-.305	.168	-.009
Compound	.926	112.444	1	9	.000	.454	1.310		
Power[a]	.	.	.	.	.	.	.		
S[b]	.	.	.	.	.	.	.		
Growth	.926	112.444	1	9	.000	-.790	.270		
Exponential	.926	112.444	1	9	.000	.454	.270		
Logistic	.926	112.444	1	9	.000	2.204	.763		

The independent variable is weightage.

a. The independent variable (weightage) contains non-positive values. The minimum value is 0. The Logarithmic and Power models cannot be calculated.

b. The independent variable (weightage) contains values of zero. The Inverse and S models cannot be calculated.

In the above model summary report we look into the R-square value for the highest value which is the most significant case when we use weightage as non-linear function in the supply chain. In this case, with the assumptions taken under for the multiplier (y) is dependent on weightage (x) to arrive at the best fit model. According to the assumptions taken based on literature, the value for the multiplier was assumed to be in the weightage likert's scale for the input to the further model.

The model for the weightage factor calculation is as following:

$y = b_1 x^3 + b_2 x^2 + b_3 x +$ constant (general cubic function model)

y – multiplier and x – weightage, b_1, b_2, b_3 are the parameter estimates

Published by: The Mattingley Publishing Co., Inc.

March-April 2020
ISSN: 0193-4120 Page No. 5970 - 5977

$$y= -0.305\ x^3 + 0.168\ x^2 -0.009\ x + 0.601 \quad (1)$$

In the equation 1, the values of x ranging from 0-10 may be given to arrive at value for y which can be taken in each case of the sub-variables which are identified for the measure of the operational performance index considering agility and resilience as the two major variables which are affecting the considerations of clusters in the food supply chain.

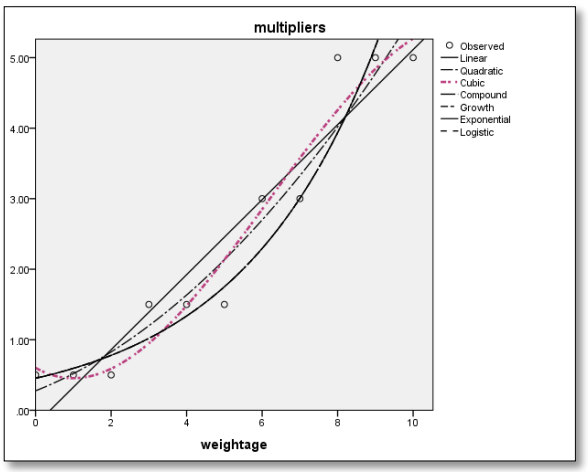

Fig: Plot showing various curve fitting techniques which are used for the input to the model

The plot shows that **cubic function of the non-linear curve fitting technique covers all the points of the distribution of the multipliers and the weightage.**

2.2 Mathematical construct for Agility and Resilience as the functional variables

At the first instance, we constructed the model using the multipliers calculation based on weightage for the dependent functions of the two variables. This is heuristics based approach which depends upon the assessment of the clusters performance correlating to agility or resilience in the supply chain. We defined the following based on literature articles for agility and resilience in the food supply chain applicable to specific clusters in the food industry:

For Agility:

$$\mu = f(J_t, K_t, L_t, M_t, N_t) \quad (2)$$

$$\mu = (W_f * J + W_f * K + W_f * L + W_f * M + W_f * N) + k \quad (3)$$

Equation 2 & 3 represents the same function where μ is termed for agility and k is function of $f(x_i)$ which is to be decided by functional owner in-case of any other parameter which are missed in this framework may be considered. J, K, L, M, N are the dimensions under agility.

J – Alertness, K – Accessibility, L – Decisiveness, M – Swiftness and N – Flexibility (These variables are arrived post brainstorming on the various literature which carried out discussion about agility in the past)

For Resilience:

$$\Omega = f(O_t, P_t, Q_t, R_t) \quad (4)$$

$$\Omega = (W_f * O + W_f * P + W_f * Q + W_f * R) + k \quad (5)$$

Where Ω is termed for resilience and k is function of $f(x_i)$ which is to be decided by functional owner in-case of any other parameter which are missed in this framework may be considered. O, P, Q, R are the dimensions under resilience.

O – Information Flow, P – Operational Flexibility, Q – Market Response and R – Intermediaries relationship

However, with further improvement in the work, the **linearity of the function**is replaced to improve the model prediction with better accuracy using the series integrated with discounted factor (δ_1) and lagged level of series (y_t -1) using the **Augmented Dickey Fuller (ADF) regression model**. It is considered that agility and resilience are the **time dependent discreet time series construct** which depends on each of the previously studied functions of agility and resilience as the indicator variable. The indicator variables are those which are discusses above which constitutes to the characteristics of the agility and resilience in the supply chain.

The regression function of the Augmented Dickey Fuller (ADF) is as follows:

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March-April 2020
ISSN: 0193-4120 Page No. 5970 - 5977

$$\Delta y_t = \alpha + \beta_t + \gamma y_{t-1} + \delta_1 \Delta y_{t-1} + \ldots\ldots + \delta_{p-1} \Delta y_{t-p+1} + \varepsilon_t \quad (6)$$

The agility and resilience are considered to be the time dependent discreet function and hence when fitted in ADF in the equation 6, it is inferred to as following:

$$\Delta \mu_t = f(J_t, K_t, L_t, M_t, N_t) \quad (7)$$

$$\Delta \mu_t = (\alpha + \beta_t + \gamma \mu_{t-1} + \delta_1 \Delta \mu_{t-1}) + (\alpha + \beta_t + \gamma \mu_{t-2} + \delta_2 \Delta \mu_{t-2}) + (\alpha + \beta_t + \gamma \mu_{t-3} + \delta_3 \Delta \mu_{t-3}) + (\alpha + \beta_t + \gamma \mu_{t-4} + \delta_4 \Delta \mu_{t-4}) + (\alpha + \beta_t + \gamma \mu_{t-5} + \delta_5 \Delta \mu_{t-5}) + \varepsilon_t \quad (8)$$

$$\Delta \Omega_t = f(O_t, P_t, Q_t, R_t) \quad (9)$$

$$\Delta \Omega_t = (\alpha + \beta_t + \gamma \Omega_{t-1} + \delta_1 \Delta \Omega_{t-1}) + (\alpha + \beta_t + \gamma \Omega_{t-2} + \delta_2 \Delta \Omega_{t-2}) + (\alpha + \beta_t + \gamma \Omega_{t-3} + \delta_3 \Delta \Omega_{t-3}) + (\alpha + \beta_t + \gamma \Omega_{t-4} + \delta_4 \Delta \Omega_{t-4}) + (\alpha + \beta_t + \gamma \Omega_{t-5} + \delta_5 \Delta \Omega_{t-5}) + \varepsilon_t \quad (10)$$

The equation (8) and equation (9) are the agility and resilient as the time-dependent function adhering to similarity and assumptions in Augmented Dickey Fuller regression model. This models provides the index for the agility and resilience.

III. Conclusion & Future Scope

The proposed model gives the measurement approach for the indicator variables (agility and resilience) on a linguistic scale. The scale is then used for to further implement the attributes of the agility and resilience in the context of supply chain. Econometric study and Augmented Dickey Fuller regression model help to redefine the measurement model in context of the research. This is a unique concept postulated in the research and assumptions of econometrics and supply chain has been correlated while consideration of the model development. The initial problem statement discussed is now resolved since it gives a time-series based measurement approach for the agility and resilience as the indicator variables. Prima-facie, the research gives a valid model which can help supply chain professionals to measure and validate their performance of the supply chain. Agility can be measured while collecting data on the linguistic scale for understanding the attributes of alertness of stakeholders in the supply chain, accessibility to the length of supply chain, decisiveness in the supply chain, swiftness and flexibility in managing functions of the supply chain (which is planning, sourcing, making, delivering and enabling). Resilience is measured based on the information flow between stakeholders, operational flexibility to appreciate the dynamics of the supply chain, external factors like market responses qualification and intermediaries' relationships for the smooth operations of the supply chain.

While the model clearly provides the sound approach to measure the performance in time-series attribute for the supply chain. The future scope of work would include to validate the measurements taken at equal interval time function and provide a final proof for the concept developed in this research

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