Supply chain resilience and measurement dimensions: The case of halal pharmaceuticals in Malaysia

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Abstract. Resilience is the vital feature of supply chains that confers the ability to withstand the adverse effects of disruptive events. Most of the previous studies have been conceptual, theoretical, normative, or at best qualitative in approach, concentrating on identifying the elements of resilience. In spite of the proliferation of studies, an empirically validated quantitative study on justifying the measurement dimensions of supply chain resilience is rare, thus the need for further quantitative empirical studies. The context of the present study is the manufacturing supply chain of *halal* pharmaceuticals in Malaysia. A quantitative cross-sectional design was applied by means of self-administered structured questionnaire survey, using the Supply Chain Resilience Assessment and Management instrument (SCRAM© 2.0). The survey yielded usable responses from 106 manufacturing companies engaged in the production of *halal* pharmaceuticals in Malaysia. Descriptive statistics as well as partial least square-based structural equation modelling was used to analyze the survey data. This was facilitated by IBM SPSS statistics software (version 21.0), and Smart PLS 3.2.4 respectively. The results suggest that the psychometric properties of the supply chain resilience dimensions (vulnerabilities and capabilities) in the context of the present study are reliable and valid.

Keywords: Supply chain, supply risks, resilience, vulnerabilities, capabilities, *halal*, pharmaceuticals

1. Introduction

Globalization in the twenty first century has brought about volatility in supply, as well as in the demand and sales of manufactured products. This has made competition stiffer, thus led business organizations to search for strategies that impart capabilities into targeted areas of their operations. The supply chain is one of such targeted areas. Ponomarov and Holcomb (2009), argue that every activity that a supply chain conducts, has inherent risk that an unexpected disruption of supply can occur. This disruption of supply is referred to as supply risk. According to Zsidisin (2003), supply risk is defined as the probability of an incident associated with supply market failures, or inbound supply from individual supplier in which its outcome results in the inability of the purchasing firm to meet customer demand, or cause threat to business continuity and survival. This is attributable to a breakdown in material and service supplies, as well as information and monetary flows between a business organization and its suppliers.

Supply chain disruptions due to events such as the loss of a crucial raw material supplier, a major fire at a production facility, or an act of terrorism have the potential to adversely affect both cost and revenue. They can lead to lost sales, as well as decline in market share. To reduce this risk, supply chains must be designed to incorporate event readiness, provide an efficient and effective response, and recover to their original state after supply disruptions. This is the essence of supply chain resilience (Ponomarov & Holcomb, 2009; Fakoor, Olfat,

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Feizi, & Amiri, 2013; Pettit, Croxton, & Fiksel, 2013; Raja, Bodla, & Malik, 2011; Chowdry & Quaddhus, 2016). Christopher and Peck (2004) define resilience as the ability of a system to return to its original state or move to a new and more desirable state after being disturbed. Thus, resilience entails a proactive approach which helps business organizations to side step avoidable risks and bounce back quickly from unexpected/unavoidable risks (uncertainties) in the supply chain. It is worthy of note that more than 80% of global companies are now concerned about supply chain resilience (Bhatia, Lane, & Wain, 2013). This is because of the increasing globalization of supply and operations, as well as market volatility of starting raw materials for production.

Over the last 13 years, resilience has dominated the discussions in the supply chain risk management literature. The important aspects of these discussions are centered on the measurement dimensions, as well as the antecedents of supply chain resilience. Based on extensive literature review (e.g Fiksel, 2006; Fakoor, *et al.,* 2013, Pettit *et al.,* 2013; Fiksel, *et al.,* 2015), a consensus is that supply chain resilience can be estimated via the measurement dimensions of vulnerabilities and capabilities. Vulnerabilities are fundamental factors that make a business organization susceptible to disruptions, while capabilities are attributes that enable a business to anticipate and overcome disruptions (Pettit *et al.,* 2013). Based on this, to pursue resilience in the supply chain, an increase level of capabilities in relation to a mitigation of vulnerabilities in the supply chain is required (Pettit *et al.,* 2010; Fakoor, *et al.,* 2013).

Moreover, Eyinda (2009) argues that the pharmaceutical manufacturing supply chain is most vulnerable to supply disruptions. However, in such a vulnerable situation, empirical evidence suggests that the supply chain of *halal* pharmaceuticals in Malaysia is thriving (Saifudin *et al.,* 2016; Selim, Zailani, & Aziz, 2018). However, a major challenge is that resilience cannot be investigated without the identification of the capabilities and vulnerabilities unique to the supply chain in context. This is because the literature argues that vulnerabilities and capabilities in a supply chain differ across different sectors and contexts in line with the specificities of the operating environment (Waters, 2008; Ponomarov & Holcomb, 2009; Barroso, Machado & Cruz 2011; Fakoor *et al*., 2013). Hence, the necessary capabilities as well as the vulnerabilities associated with the supply chain resilience of *halal* pharmaceuticals in Malaysia is worthy of investigation, and examination. Thus, inspired by the industry's apparent growth despite numerous adversities, it is pertinent to examine the reliability and validity of the measurement dimensions (capabilities and vulnerabilities) of the supply chains of companies engaged in the production of *halal* pharmaceuticals in Malaysia. By achieving this, the objective of the present research is met.

2. Literature review

In supply chain literature, conceptualization of supply chain resilience can be analyzed from different perspectives. Some of the studies shed light on building resilience capabilities upfront such as flexibility, visibility, redundancy, collaboration, disaster readiness, financial strength, market capability, etc. (Erol *et al.,* 2010; Pettit, *et al.,* 2013; Jüttner & Maklan, 2011; Pal *et al.,* 2014;), whereas other studies focus on resilience capabilities after the act, such as recovery time, cost and response effort (Sheffi & Rice, 2005; Christopher & Peck, 2004; Falasca Zobel, & Cook, 2008). These two notions of resilience capabilities are also interchangeably defined as pre-disruption resilient actions and post disruption resilient actions (Rose, 2004).

However, despite the increasing number of papers published on supply chain resilience, there has been little application of quantitative modeling techniques to the subject matter; in general, most papers have simply provided qualitative insights into the problem. Most analyses on supply chain resilience have failed to draw conclusions about causalities between supply chain practices and supply chain resilience, but only answer explorative questions without providing any statistical evidence of the findings. Previous studies would have been more convincing if they had drawn statistical inferences from quantitative results, and the conclusions might have been more interesting. It is however worthy of mention that this issue has recently been given consideration by contemporary researchers on supply chain resilience (e.g Falasca, *et al.,* 2008; Pettit *et al.,* 2013; Fakoor *et al.,* 2013; Chowdhury & Quaddus; 2016).

The study of Pettit *et al.* (2013) was based on extant literature and refined through a focus group methodology with respondents gathered from seven global manufacturing supply chains in the consumer goods, and chemical manufacturing industries. Their findings reveal that vulnerabilities and capabilities are two measurement dimensions of supply chain resilience that must be identified in the investigation of supply chain resilience. It is thus imperative to state that this is a necessary step in supply chain resilience research. An improvement in the resilience of supply chain thus requires enhancement of the capabilities and mitigation of the vulnerabilities (Barroso, *et al.,* 2011; Fakoor, *et al.,* 2013; Pettit, *et al,* 2010). Furthermore, Pettit, *et al.* (2010) developed a quantitative questionnaire survey assessment instrument named Supply Chain Resilience Assessment and Management (SCRAM©) instrument. This assessment instrument which is anchored on a 5-point Likert scale response (1- strongly disagree to 5 – Strongly agree) enables the assessment of the vulnerabilities, and the capabilities of a supply chain from the judgements of supply chain experts who are knowledgeable on the supply chain operations of their organizations. Fakoor *et al.* (2013) successfully applied the SCRAM© in gathering data from supply chain executives in the Iranian automotive industry. They quantified the views of the respondents regarding vulnerabilities and capabilities.

3. Methodology

This paper is part of a larger study on supply chain resilience. The findings from a semi-structured interview conducted via a phenomenological qualitative method have been reported (see Aigbogun et al., 2014). This revealed four vulnerability indicators (turbulence, external pressures, sensitivity, and connectivity); and six capability indicators (flexibility, reserve capacity, visibility, adaptability, collaboration, and supplier dispersion) unique to the supply chain of halal pharmaceuticals in Malaysia. For the present study, a questionnaire-based survey in a cross-sectional time horizon was applied. This survey was carried out by means of a self-administered structured type questionnaire (SCRAM© 2.0) distributed directly to the research population. All variables of interest were estimated through the respondents' perceptual evaluation of their companies' products and operations on a 5-point Likert-type scale, which was anchored by 1 (Strongly disagree) and 5 (Strongly agree). All the measurement items used have been adopted from previously established measurement scales (SCRAM© 2.0). Thus, the validity of these items has been previously evaluated. However, it is possible that the differences that exists in the context, scope and environment of the present research necessitates a formal content validity test to be carried out. In doing this, the initial pool of items was given to a panel of 16 experts to be reviewed, and their comments and suggestions were used to refine and modify the questionnaire items.

The sample unit of analysis was manufacturing company engaged in the production of halal pharmaceuticals in Malaysia. Each company was represented (the respondents) by either senior production manager, supply chain manager or senior executive in purchasing/logistics/planning/scheduling. The sampling frame was the 2015 list prepared by Jabatan Kemajuan Islam Malaysia (JAKIM), of companies engaged in production of halal pharmaceutical in Malaysia. In Malaysia, JAKIM is the regulatory authority charged with the responsibility to formulate and standardize the laws and regulations necessary to evaluate and coordinate the implementation of halal standards in Malaysia. The sample size was calculated to be 104 companies (Krejcie and Morgan, 1970). Partial Least Squares (PLS) technique as a part of Structural Equation Modelling (SEM) was used to model supply chain resilience as a third-order hierarchical model of the measurement dimensions in formative mode. Based on the guideline of previous studies (Christopher & Peck, 2004; Jüttner & Maklan, 2011; Chowdhury & Quaddus, 2016) and the decision rules of Jarvis et al. (2003), formative measurement mode was selected for measuring the dimensions of supply chain resilience. The measurement dimensions of supply chain resilience were analyzed through the examination of indicator weight (w), loading (l) and variance influence factor (VIF) (Hair et al., 2011).

4. Results and discussion

4.1 Descriptive Statistics of Research Constructs

The responses from the survey respondents were anchored on a 5-point Likert scale with ‘1’ being strongly disagree, and ‘5’ strongly agree. Hence, according to the recommendation of Boone & Boone (2012) for Likert scale data, the mean and standard deviation was applied as a measure of central tendency and variability respectively. Thus, any average of above 3.0 was considered good as this indicated the level of the respondents’ agreement to those statements representing the constructs tested. Table 1 shows the descriptive statistics output of the research constructs. The means and standard deviations were arrived at by computing the average of the means of their respective items.

Table 1: Descriptive Statistics of Research Constructs

	N	Min	Max	Mean	Std. Dev.
TB	106	1.00	5.00	2.918	0.903
EP	106	1.00	5.00	3.110	0.895
STY	106	1.00	5.00	3.785	1.028
CTY	106	1.00	5.00	3.515	0.771
FBY	106	1.00	5.00	3.740	0.751
VBY	106	1.00	5.00	2.830	0.831
CBN	106	1.00	5.00	3.120	0.881
ADY	106	1.00	5.00	2.919	0.927
CPY	106	1.00	5.00	3.359	0.956
SD	106	1.00	5.00	2.905	1.029

Source: survey data
Legend:
TB= Turbulence; EP= External pressures; STY= Sensitivity; CTY= Connectivity; FBY= Flexibility; VBY= Visibility; CBN= Collaboration; ADY= Adaptability; CPY= Capacity; SD= Supplier dispersion

The results reveal that EP (3.110), STY (3.785), CTY (3.515), FBY (3.740), CBN, (3.120), and CPY (3.359), had their mean values above the mid-point level of 3.0, while TB (2.918), VBY (2.830), ADY (2.919), SD (2.905) had a mean value less than 3.0. However, a computation of the average of these mean values revealed an average of 3.220. This phenomenon indicates that the consensus respondents’ perception towards the measurement dimensions of supply chain resilience was generally above the average when computed together. The standard deviation was applied as a dispersion index to indicate the degree to which respondents within each construct differ from the mean of the construct. From the results, it is observed that the standard deviation value (1.029) of SD deviated the most from its mean. This value suggests that the survey respondents were most varying in this construct from each other. On the other hand, the lowest deviation from mean was FBY with a standard deviation of 0.751.

4.2. Assessment of the First Order Measurement Dimensions of Supply Chain Resilience (Formative Mode)

The outer weights and outer loadings for each measurement item of the first-order formative constructs of supply chain resilience measurement model were analyzed. Among the original 48 items, 43 had significant weights and loadings above the recommended minimum threshold values. The remaining 5 items with insignificant weights and loadings were dropped from the model (Hair *et al.*, 2011). The items that were dropped are V1.2, V3.3, V3.6, C2.1, C4.1, and they make up a total of 6.9% of the total number of item measures. The trimmed model was rerun and revaluated. Furthermore, the collinearity among the first-order formative constructs was examined by means of their respective VIF values. The Table 2 is a summary of the trimmed model showing the outer weights, and outer loadings, with their respective t-values and p-values, as well as the collinearity statistics (VIF) at the first-order level in the formative mode.

Table 2: Psychometric property of supply chain resilience measurement dimensions at first-order level

First- order construct	Items	Weights			Loadings			VIF
		W	*t*-value	*p*-value	*l*	*t*-value	*p*-value	
TB	V1.1- Cust. demand unpredictability	0.484	2.852	0.004	0.851	2.720	0.005	2.032
	V1.2- Sup. currency/price fluctuation*****							
	V1.3- Supplier geopolitical disruptions	0.641	8.213	0.000	0.761	2.126	0.028	2.390
	V1.4- Exposure to natural disasters	0.496	4.115	0.000	0.812	4.185	0.000	2.177
	V1.5- Unforeseen technology failures	0.364	2.951	0.001	0.918	3.038	0.000	1.957
EP	V2.1- Competitive innovation	0.567	8.625	0.000	0.911	2.580	0.007	1.563
	V2.2- Price pressures	0.635	4.682	0.000	0.961	2.705	0.006	2.824
	V2.3- Corporate responsibility	0.184	4.462	0.000	0.691	2.836	0.004	2.661
	V2.4- Social/Cultural issues	0.316	1.796	0.063	0.784	2.892	0.002	1.752
STY	V3.1- Presence of restricted materials	0.179	6.913	0.000	0.711	4.119	0.000	1.023
	V3.2- Importance of supply purity	0.237	3.872	0.000	0.782	9.065	0.000	2.805
	V3.3- Stringency of manufacturing*****							
	V3.4- Fragility of handling	0.120	0.901	0.089	0.898	4.903	0.000	2.378
	V3.5-Stakeholder visibility	0.365	22.213	0.000	0.880	19.237	0.000	2.171
	V3.6- Symbolic profile of brand*****							
	V3.7- Customer quality requirement	0.483	13.326	0.000	0.854	8.457	0.000	1.917
CTY	V4.1- Scale of supply network	0.206	2.213	0.027	0.869	7.751	0.000	1.638
	V4.2- Extent of supply network	0.214	3.336	0.000	0.637	2.050	0.031	1.774
	V4.3- Reliance upon specialty sources	0.217	11.110	0.000	0.949	2.892	0.002	1.741
	V4.4- Reliance upon information flow	0.209	5.129	0.000	0.632	2.851	0.003	1.606
	V4.5- Degree of outsourcing products	0.234	1.694	0.069	0.718	4.859	0.000	2.211
	V4.6- Degree of outsourcing package	0.233	3.261	0.000	0.664	4.985	0.000	2.161
FBY	C1.1- Common product platforms	0.536	3.693	0.000	0.851	2.631	0.007	2.193
	C1.2- Supply contract flexibility	0.445	6.102	0.000	0.796	21.666	0.000	1.928
	C1.3- Supplier capacity	0.303	2.998	0.001	0.685	19.164	0.000	1.434
	C1.4- Supplier expediting	0.337	9.613	0.000	0.750	2.948	0.001	2.984
	C1.5- Alternate suppliers	0.149	2.343	0.021	0.779	15.964	0.000	3.327
VBY	C2.1- Information technology*****							
	C2.2- Status of inventory	0.297	2.871	0.002	0.715	14.371	0.000	2.355
	C2.3- Status of personnel	0.605	4.216	0.000	0.932	35.804	0.000	3.799
	C2.4- Information exch. with suppliers	0.239	6.128	0.000	0.905	34.062	0.000	3.018
	C2.5- External monitoring	0.386	5.113	0.000	0.711	5.112	0.000	3.347
CBN	C3.1- Supply chain communication	0.171	2.222	0.028	0.854	24.719	0.000	2.935
	C3.2- Sup. involvement in innovation	0.413	5.842	0.000	0.909	43.599	0.000	2.982
	C3.3- Postponement of orders	0.517	7.101	0.000	0.924	41.312	0.000	2.176
	C3.4- Supplier collaboration	0.565	19.828	0.000	0.654	5.190	0.000	1.117
ADY	C4.1-Seizing advtg from disruptions*****							
	C4.2- Alternative technology	0.455	15.392	0.000	0.740	31.111	0.000	2.681
	C4.3- Strategic techniques	0.157	2.040	0.032	0.917	26.069	0.000	2.793
	C4.4- Environmental sustainability	0.335	3.981	0.000	0.685	20.057	0.000	2.568
CPY	C5.1- Backup utilities	0.706	1.976	0.042	0.650	15.908	0.000	2.552
	C5.2- Raw materials	0.707	3.687	0.000	0.935	2.246	0.025	2.918
	C5.3- Reserve capacity	0.421	4.582	0.000	0.806	1.976	0.043	3.486
	C5.4- Labor capacity	0.340	1.991	0.039	0.718	1.968	0.047	3.155
SD	C6.1- Distributed suppliers	0.407	6.710	0.000	0.755	18.139	0.000	1.323
	C6.2- Distributed production	0.367	4.723	0.000	0.841	23.431	0.000	1.975
	C6.3- Dispersed distribution	0.249	2.918	0.001	0.833	25.686	0.000	2.771
	C6.4- Distributed raw materials	0.257	3.250	0.000	0.796	21.123	0.000	2.605

Source: survey data

*Note: * Items with low loadings and weights were dropped*

As observed from the Table 3, the bootstrapping results of the trimmed model show that the indicator item weights (*w*) and loadings (*l*) with their corresponding t-values and p-values of the supply chain resilience measurement model at first-order level were significant at the 95% confidence level (t>1.96; p>0.05). Three indicators (V2.4, V3.4 and V4.5), had insignificant weights, but they had significant loadings which were greater than 0.5, and hence were retained (Hair *et al.,* 2014). According to Hair *et al.* (2011), in specific instances (i.e. when the indicator weight is not significant), the researcher also needs to evaluate the bivariate correlation (loading) between the (nonsignificant) indicator and the construct to decide whether to exclude the indicator from the outer model. Also, as observed from the Table 2, the VIF values for each indicator corresponding to the respective construct is less than the recommended minimum threshold of 5, therefore, multicollinearity problem does not exist (Hair *et al*., 2011). Also, the VIF values obtained assured that there was no common method bias (Kock, 2012)

4.3. Assessment of the Second Order Measurement Dimensions of Supply Chain Resilience

The Table 3 shows the psychometric property of supply chain resilience measurement dimensions at the second-order level. The Table is a summary showing the outer weights, and outer loadings, with their respective t-values and p-values at second-order level in the formative mode.

Table 3: Psychometric property of supply chain resilience measurement dimensions at second-order level

Second order Formative constructs	First order formative constructs	Weights			Loadings		
		w	*t*-value	*p*- value	*l*	*t*-value	*p*- value
Vulnerabilities	TB	0.589	2.827	0.004	0.741	2.521	0.008
	EP	0.588	4.905	0.000	0.859	4.309	0.000
	STY	0.319	2.449	0.011	0.795	2.067	0.029
	CTY	0.478	2.951	0.001	0.554	5.868	0.001
Capabilities	FBY	0.492	4.173	0.000	0.791	5.309	0.000
	VBY	0.367	3.681	0.000	0.670	3.113	0.000
	CBN	0.685	7.494	0.000	0.881	2.912	0.001
	ADY	0.346	3.974	0.000	0.692	7.118	0.000
	CPY	0.338	1.971	0.044	0.553	4.901	0.000
	SD	0.362	2.117	0.000	0.614	9.137	0.000

Source: survey data

As observed from the Table 3, the bootstrapping results of the model run show that all the indicator weights and loadings with their corresponding t-values and p-values of the supply chain resilience measurement model at second-order level were significant at the 95% confidence level (t>1.96; p>0.05).

4.4. Assessment of the Third Order Measurement Dimensions of Supply Chain Resilience

The Table 4 is the psychometric property of supply chain resilience measurement dimensions of the present study at the higher-order level. The Table is a summary showing the outer weights, and outer loadings, with their respective t-values and p-values at second-order level in the formative mode.

Table 4: Psychometric property of supply chain resilience measurement dimensions at higher-order level

Higher-order construct	Second order formative constructs	Weights			Loadings		
		W	*t*-value	*p- value*	*l*	*t*-value	*p- value*
Supply Chain Resilience	Capabilities	0.586	7.434	0.000	0.837	18.223	0.000
	Vulnerabilities	0.494	6.162	0.000	0.762	11.134	0.000

Source: survey data

As observed from the Table 4, the bootstrapping results of the model run show that all of the indicator weights and loadings with their corresponding t-values and p-values of the supply chain resilience measurement model at higher-order level were significant at the 95% confidence level ($t>1.96$; $p>0.05$).

5. Conclusion

Research scholars Jaafaar *et al.* (2011), as well as Ngah, *et al.* (2014) have argued that despite of several researches related to *halal* that has been carried out, research in the supply chain context of *halal* pharmaceuticals in very much limited. As a result, the findings from the present research, contributes immensely to the supply literature on *halal* pharmaceuticals in an area that has been somewhat neglected.

In addition, the reliability and validity results of the assessment of the measurement dimensions of the hierarchical supply chain resilience (SCRes) formative measurement model, confirmed that the constructs have adequate psychometric properties corresponding to their respective measurement items.

The present research was built upon the research model of Pettit *et al.* (2013) as well as Chowdhury and Quaddus (2016), and contextualized. Thus, the present research characterizes a hierarchical (third-order level) supply chain resilience model in terms of the measurement dimensions of vulnerabilities and capabilities of the manufacturing supply chain of *halal* pharmaceuticals in Malaysia. This hierarchical model is similar to that of Chowdhury and Quaddus (2016). However, it improves on it, because the measurement dimensions (vulnerabilities and capabilities) of supply chain resilience suggested by Pettit *et al.* (2013) was applied, as against readiness capability, and response recovery dimensions used by Chowdhury and Quaddus (2016). This is because Pettit *et al.* (2013) supply chain residence measurement dimensions (vulnerabilities and capabilities) captures a wider range of indicators and measures which is apt for a global industry like pharmaceuticals, relative to supply chain residence measurement dimensions (readiness capability and response recovery) applied by Chowdhury and Quaddus (2016). As a result of this blend, the hierarchical supply chain resilience model applied in the present research, lays a solid theoretical foundation for future research on supply chain resilience.

6. References

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