The Mediator Effect of Supply Chain Agility on Firm Performance

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Abstract

While it is generally acknowledged that an organization's supply chain agility is crucial to its competitive advantage, the impact of agility on firm performance has not been adequately researched. This research uses structural equation modeling to examine the effect of supply chain agility on firm performance. This study first presents a supply chain agility framework based on the key elements that determine the flexibility attributes of a firm's critical supply chain processes related to sourcing, manufacturing, and logistics. Next, the study describes the relationships between the elements of flexibility and supply chain agility. A set of survey data is used to examine the relationships between the constructs in the proposed research model. Survey results show that a firm's supply chain agility can be measured by two second-order constructs consisting of its information technology capability and supply chain flexibility. Additionally, the results show that supply chain agility affects firm performance through its competency in responding to the changing market environment.

1. Introduction

It is widely acknowledged that a firm's supply chain agility directly affects its ability to efficiently design, produce, and deliver innovative products to its customers. Supply chain agility can be broadly defined as a firm's ability to rapidly respond and adapt to unexpected changes in the market conditions. To gain competitive advantage in this intensely volatile and competitive global market, firms must align with key suppliers and customers to streamline operations and collaborate to achieve superior supply chain agility. Indeed, supply chain agility has been proposed as an essential strategic element of time-based competition [1]. While the concept has gained popularity as an emerging paradigm for enhancing competitive edge [2], the impact of supply chain agility on firm performance is not well understood. Moreover, little research exists to date that addresses how a firm can achieve superior supply chain agility. There is also limited consensus in the literature on how supply chain agility should be measured [1][3][4]. This study focuses on supply chain agility internal to the firm. Understanding the agility of a firm is the precursor to the analysis of agility involving multiple firms in a supply chain.

A central characteristic of supply chain agility is the flexibility of a firm in responding to unexpected changes in the market and demand conditions [5]. The origin of supply chain agility as a key business concept can be traced back to flexible manufacturing systems where automation and cellular manufacturing were exploited to promote rapid and cost effective changeovers [6][1]. Flexible manufacturing systems stress *economy of scope* to minimize production costs, yet offer design, volume, and delivery flexibility. Although manufacturing flexibility has been well researched [7][8][9][10], the literature tends to focus on manufacturing but ignores the procurement and logistics processes. Indeed, the potential benefits derived from improving the procurement and logistics processes should significantly outweigh the results from improving the manufacturing process since a firm typically spends at least 50% and roughly 10% of its sales on purchases and logistics activities respectively [11][12].

In a recent study, [13] proposed that a firm's process flexibility is the key antecedent of supply chain agility. The authors established the determinants of the flexibility attributes of the crucial processes of procurement, manufacturing, and logistics functions of a firm, and showed that flexibility in these three areas affect supply chain agility. In a related study, [14] presented a supply chain agility framework and attempted to identify the drivers and determinants of supply chain agility. The authors proposed that a firm's information technology (IT) capability impacts the levels of achieved flexibility and agility, which successively impacts firm performance. They concluded that firms achieved higher levels of agility through integrating information across the supply chain rather than within specific supply chain activities. However, the authors did not find any significant relationships between a firm's sourcing information technology capability and sourcing flexibility, or between a firm's manufacturing information technology capability and manufacturing flexibility. Also, their study revealed a counterintuitive result about the relationships between supply chain agility and performance. For example, manufacturing range, a latent variable designed to measure the range of product variety and production capacity, was inversely related to time to market, and logistics adaptability was weakly correlated with on-time delivery.

Undoubtedly, possessing high supply chain agility enables a firm to react swiftly to marketplace volatility and demand uncertainties, thereby enabling the firm to be more efficient in synchronizing demand with supply, and thus help to establish a superior competitive position. Given that supply chain agility affects a firm's ability to design, produce, and deliver innovative products to customers, we believe that supply chain agility is a crucial factor affecting a firm's overall global competitiveness. Unfortunately, little research exists that addresses how a firm can achieve supply chain agility, and virtually no research has been done to empirically examine the impact of supply chain agility on firm performance. This study addresses this gap by using the literature to identify and develop the critical constructs that determine and influence a firm's supply chain agility and the subsequent impact of supply chain agility on firm performance. Building on the process-based supply chain agility framework of [13], we propose that supply chain agility is derived from the flexibility attributes of a firm's procurement, manufacturing, and logistics processes. A set of survey data was used to test and refine the research model.

The next section describes the theoretical framework and hypotheses of the study. Then, we present the statistical analysis and refinement of the research model, followed by a discussion of the ensuing results. Next, we conclude with a brief discussion of the managerial and research implications of our results and the limitations of the study.

2. A Conceptual Framework of Supply Chain Agility

The origin of supply chain agility can be traced to flexible manufacturing systems when manufacturers attempted to build agility into their operations in the 1960s [1]. An agile operations strategy utilizes outstanding flexible manufacturing capabilities to efficiently balance supply and demand. Supply chain agility extends manufacturing agility to include a firm's procurement and logistics processes to complete the value adding activities of a firm. Thus, understanding the complexity of supply chain agility within a firm is the natural extension of the study in manufacturing flexibility, and it is the gateway to supply chain agility research involving multiple firms in a supply chain.

Consistent with the literature, we define supply chain agility as the capability of a firm to quickly react and adapt to market changes or to seize and exploit emerging market opportunities effectively [13][14]. While flexibility and agility are often defined as the ability to rapidly react and adapt to unexpected changes, flexibility and agility are different concepts. Using the commonly accepted paradigm in the strategy literature, we defined supply chain agility as an externally focused capability derived from flexibilities in the supply chain processes. Flexibilities in the supply chain processes are defined as internally focused competencies [15][16]. Consistent with the literature, we posit that agility and flexibility are distinct yet related concepts, with flexibility as an antecedent of agility (Figure 1). Supply chain flexibility measures a firm's internal and integration IT capabilities, range, and adaptability, whereas supply chain agility measures a firm's ability to react and adapt to changing market conditions.

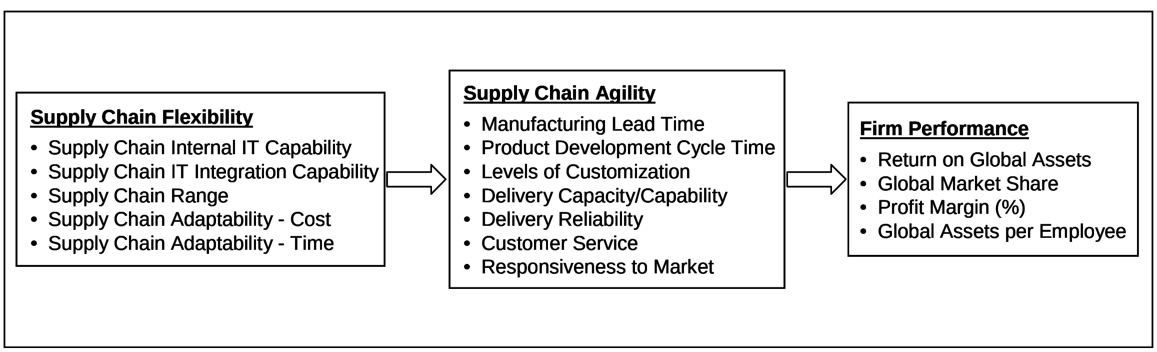


Figure 1: Theoretical Research framework

The process-based view of a supply chain posits that the three key value-adding segments of an organization are the procurement, manufacturing, and logistics processes [15][17]. Building on this widely accepted framework, we hypothesize that the key antecedents of a firm's supply chain agility are the inherent flexibility dimensions in these key processes in terms of the firm's internal IT capability, IT integration capability, range, and adaptability in cost and time. The combined effect of these supply chain process flexibilities affects a firm's supply chain agility, or its capability to rapidly adapt and respond to changing marketplace environment. Clearly, a firm that possesses higher levels of agility is likely to outperform a firm that is incapable of responding to a changing market environment efficiently.

2.1 Dimensions of Supply Chain Flexibility

Supply chain flexibility is a complex, multi-faceted construct. Consistent with the literature, we operationalize supply chain flexibility in terms of a firm's internal IT capability, IT integration capability, supply chain range, and cost and time adaptability [13][14]. Each of these constructs are described below.

We operationalize supply chain internal IT capability in terms of a firm's use of information technology to coordinate and integrate activities in product development, procurement, manufacturing, and logistics processes, and the use of enterprise-wide software to manage global supply chain activities. Information technology enables a firm to gather, store, and process information needed to make strategic business decisions. Efficient enterprise-wide information technology not only allows firms to integrate information and coordinate activities within a functional area, it also allows firms to integrate across organizational boundaries. Possessing well-designed and implemented information technology minimizes errors and reduces response time, thus positively impacting supply chain agility. The nature and extent of information technology used in a firm has been well-addressed. For example, [18] found that the use of information technology in product design affects supply chain agility. Additionally, [5] showed that process and network integration is an important element affecting supply chain agility. Through process and network integration, firms can progress from echelon logistical structure to mixed logistical structure. Thus, we propose that (Figure 2):

H_{1a}: Supply chain internal IT capability (IntrCap, ξ_1) directly affects a firm's supply chain agility (SCA, η_6), i.e., statistically significant parameter estimate $\gamma_{6,1}$.

H_{1b}: Supply chain IT integration capability (IntgCap, ξ_2) directly affects a firm's supply chain agility (SCA, η_6), i.e., statistically significant parameter estimate $\gamma_{6,2}$.

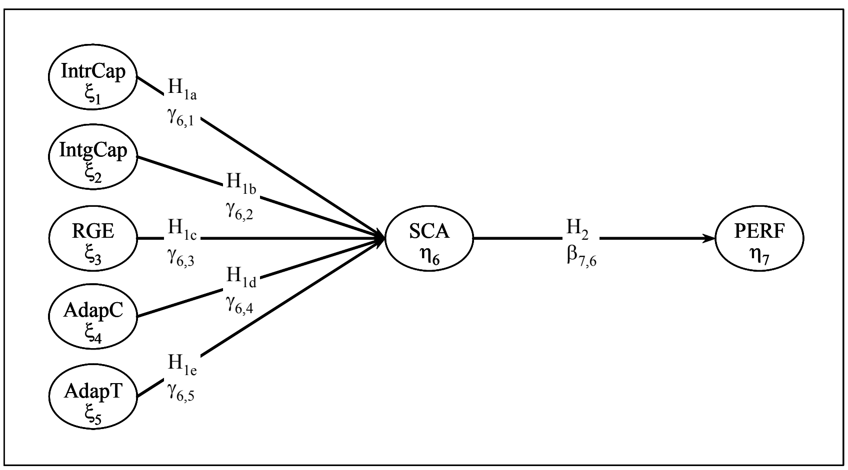


Figure 2: Proposed Direct Effect Supply Chain Agility Structural Equation Model

While there is no general consensus on the dimensions to measure flexibility, we adopt Slack's definition [19] that flexibility is the range that is feasible for a firm to adjust its processes to meet changing demand, the cost incurred to make the adjustment, and the time for the change. Upton [7] defined flexibility as the ability to change within a range with little penalty in time or cost. Subsequently, citing [7], Koste and Malhotra [9] used range to describe manufacturing flexibility. A firm can exhibit flexibility in various ways [19]. That is, it may exhibit flexibility by having a large range of options to exercise, or by reducing the cost and time associated with utilizing its options. For example, a firm that is capable of producing a large range of products exhibits more flexibility than a firm that is capable of producing a small range of products if both firms incur the same cost and time to change the product mix. We operationalize supply chain range in terms of a firm's flexibility in product variety, lead time, delivery frequency, and lot size.

Slack [19] also argued that the cost and time incurred for adapting to a new stage are crucial attributes of supply chain flexibility. However, adaptability to higher cost and the ability to tolerate longer lead times are opposing characteristics of flexibility. For example, lead time can be reduced using overtime and premium delivery service, and thus driving up cost. Conversely, cost can be reduced at the expense of longer delivery lead time. Slack [20] found that practitioners considered range flexibility and response flexibility as the two critical aspects of flexibility in a firm. Response flexibility is defined as the ease, in terms of cost and time, with which changes can be made.

Based on the literature, it is clear that range, cost and time are crucial dimensions for measuring supply chain flexibility. Consistent with the literature [7][19], we defined range as the number of different states that can be achieved with existing resources. The final two dimensions of flexibility combined constitute a firm's adaptability in terms of cost and time. Adaptability is the ability to change within a given state [21]. We expanded the definition to include the ability to change from one state to another state in a timely and cost effective manner to capture the cost and time aspects of a firm to exercise its flexibility. This is consistent with the recent study by Koste, Malhotra, and Sharma [22]. Thus, we hypothesize that (Figure 2):

H_{1c}: Supply chain range (RGE, ξ_3) directly affects a firm's supply chain agility (SCA, η_6), i.e., statistically significant parameter estimate $\gamma_{6,3}$.

H_{1d}: Supply chain cost adaptability (AdapC, ξ_4) directly affects a firm's supply chain agility (SCA, η_6), i.e., statistically significant parameter estimate $\gamma_{6,4}$.

H_{1e}: Supply chain time adaptability (AdapT, ξ_5) directly affects a firm's supply chain agility (SCA, η_6), i.e., statistically significant parameter estimate $\gamma_{6,5}$.

2.2 Supply Chain Agility

Supply chain agility addresses the supply chain's capability to respond promptly to the changing marketplace environment. It represents an outcome or externally focused concept, and is thus regarded as a capability, instead of a competency. Therefore, a firm's supply chain agility deals with the capability of the firm to respond or react rapidly to key supply chain outcome measures, not how effectively the outcome measures are achieved. Based on the literature, the key measures for supply chain agility are shown in Table 1. These measures capture the speed and/or responsiveness with which a firm's supply chain can respond. For example, supply chain agility measures include how quickly a firm can reduce manufacturing lead times, or increase levels of customization, but exclude measures of the level of lead time performance or customer service performance. It is important to understand that while these measures may resemble performance metrics, they are conceptually different in that supply chain agility represents how rapidly these outcomes can be changed, and not the level of attainment of these outcomes or performances. Based on our notion that supply chain agility is an externally focused capability that is derived from flexibilities in the supply chain processes, we posit that supply chain agility positively impact firm performance. Thus, we hypothesize that (Figure 2):

H_2: Supply chain agility (SCA, η_6) positively affects firm performance (PERF, η_7), i.e., statistically significant parameter estimate $\beta_{7,6}$.

3. Data Collection and Sample Characteristics

Surveys were mailed to senior executives of manufacturing firms identified from Dunn and Bradstreet, members of the Council of Logistics Management and Supply Chain Council. Senior executives were selected because they would be more familiar with their firm's strategic goals and operations and have full access to needed information. To ensure responding firms have reasonable exposure to contemporary supply chain practices, such as flexibility and agility, firms with less than 100 employees were excluded for the survey. The survey was conducted using Dillman's [23] survey methodology.

Survey respondents were asked to answer each question using a 5-point Likert scale (1-low, 5-high) based on the characteristics of their business unit relative to their major competitors. For the firm's internal capability and integration capability in terms of information technology, respondents were asked to indicate the extent to which their business unit engages in each of the relevant information technology activities. For supply chain range, respondents were asked to indicate the level of the relevant characteristics associated with sourcing, manufacturing, and logistics functions in their business unit. For supply chain cost and time adaptability, respondents were asked to indicate the average level of cost and speed associated with engaging in the relevant sourcing, manufacturing, and logistics activities in their business unit respectively. For supply chain agility, respondents were asked to indicate the speed or the degree of responsiveness with which their business unit can engage in the relevant activities in their business unit. Next, respondents were asked to indicate the overall performance of their business unit compared to major competitors along the dimensions listed. Table 1 summarizes the survey questions.

One hundred and fifteen useable responses were received from 607 surveys mailed, thus yielding a response rate of 19%. The respondents represent multiple industries with an average annual sales volume in the range of $101-250 million and an average number of employees in the range of 501-1000. Slightly more than a quarter of the respondents are in the industrial machining sector, whereas electrical equipment manufacturers make up 20% of the respondents. Fabricated metal product, transportation, optical, watch, and measuring instrument manufacturers are also represented in the sample. More than 60% of the firms provide some level of product customization and achieve low to moderate volumes of sales. While respondents of the survey are mostly vice presidents of supply chain, manufacturing, operations or logistics, the predominant respondents are vice president of manufacturing (38.3%).

4. Non-Response Bias and Common Method Variance

T-tests on sales volume, number of employees, manufacturing environment, and three randomly selected measures from Table 1 did not reveal any statistical difference (α = 5%) between early and late respondents, suggesting that non-response bias is not a problem for this study [24][25]. The Harman one-factor method suggests that if common method bias is a problem, a single factor will emerge or a general factor will account for most of the variance in the data. Exploratory factor analysis of the measures yielded multiple factors, thus suggesting that common method bias was not a problem [26][27].

5. Statistical Analysis

Structural equation modeling was used to test the proposed research model. This study adopted a widely recommended two-step modeling approach where the fit of the structural model was assessed independently of the measurement models [28][29][30]. The measurement models address the reliability and validity of the indicators in measuring the constructs, whereas the structural model specifies the direct and indirect relations among the latent variables and describes the amount of explained and unexplained variance in the model. Another advantage of the two-step modeling approach is that if each measurement model is identified independently, then the structural model is identified [31]. Lisrel 8.72 was used to analyze the hypothesized models. The maximum likelihood estimation method, which has desirable asymptotic properties, was used in this study. This estimation method assumes multivariate normality of the observed variables and a sufficient condition is that the observations must be independently and identically distributed [30]. However, recent research has shown the maximum likelihood method can be used for data with minor deviations from normality [32].

5.1 Analysis of the Measurement Models

The first measurement model tested was the *supply chain internal IT capability* (IntrCap) model. The model was first checked to ensure parameter estimates exhibit the correct sign and size and are consistent with the underlying theory [28]. While the five indicators were statistically significant, modification indices suggested to add an error covariance between the errors of the two indicators, *the use of IT to coordinate and integrate activities in logistics and distribution* (X_{A4}) and *ERP or SC planning software is used to manage global supply chain activities* (X_{A5}). Since information technology used to coordinate logistics and distribution activities usually refer to some form of ERP or supply chain planning software, an error covariance was added, and the supply chain internal capability measurement model was modified accordingly (Table 1). With the exception of the last indicator, standardized factor loadings for the construct were sufficiently large, exceeding 0.50. Factor loading describes the relation between the observed measure and its latent variable, and indicates the ability of the observed measure to measure the corresponding construct and serves as a validity coefficient.

Next, the *supply chain IT integration capability* (IntgCap), *supply chain range* (RGE), and *supply chain cost adaptability* (AdapC) measurement models were tested (Table 1). These three measurement models were straight forward, and no error covariance term was added. Although a couple of the factor loadings were relatively low (X_{C11} = 0.26, X_{C13} = 0.29) for the *supply chain range* measurement model, the indicators were, however, theoretically crucial to the construct and statistically significant (α = 5%). They were thus left in the model as suggested by the literature [28][30][31][32]. Subsequently, the *supply chain time adaptability* (AdapT), *supply chain agility* (SCA) and *firm performance* (Perf) measurement models were tested, and an error covariance was added to each of these models. For the *supply chain time adaptability* construct, an error covariance term was added to link the indicators, *alter delivery schedules to meet changing customer requirements* (X_{E24}) and *reduce manufacturing throughput times to satisfy customer delivery* (X_{E27}) since a perceptive manufacturer is likely to adopt these strategies concurrently to improve delivery performance and customer service. Error covariance terms were added to link the indicators, *improve level of customer service* (X_{F32}) with *improve delivery reliability* (X_{F33}) in the supply chain agility model, and *global market share* (X_{G36}) with *total worldwide sales* (X_{G38}) in the firm performance model. The rationales for the error covariance are that one would expect a firm's delivery performance to affect customer service, and total worldwide sales to determine the global market share of a firm. Overall, parameter estimates for the seven measurement models exhibit the correct sign and size, and are consistent with the underlying theory (Table 1).

Table 1: Measurement Models – Factor Loadings and Composite Reliabilities

Constructs	Measured Variables/Indicators	Std Factor Loadings (λ)	Composite Reliabilities
(ξ_1) Supply Chain Internal IT Capability [IntrCap] (Standardized Cronbach's α = 0.785)			
X_{A1}	The use of IT to coordinate and integrate activities in design & development	0.55	0.781
X_{A2}	The use of IT to coordinate and integrate activities in procurement & sourcing	0.77	
X_{A3}	The use of IT to coordinate and integrate activities in manufacturing	0.76	
X_{A4}	The use of IT to coordinate and integrate activities in logistics and distribution	0.68	
X_{A5}	ERP or SC planning software is used to manage global SC activities	0.44	
(ξ_2) Supply Chain IT Integration Capability [IntgCap] (Standardized Cronbach's α = 0.846)			
X_{B6}	Internet or B2B technologies are used to coordinate and manage the SC	0.59	0.849
X_{B7}	The firm's IT infrastructure is used to provide a competitive advantage	0.75	
X_{B8}	Firm's IT infrastructure is used to identify global mkt trends for finished goods	0.72	
X_{B9}	Firm's IT infrastructure is used as a key enabler to integrate all SC activities	0.85	
X_{B10}	Firm's IT infrastructure is used as a key enabler of communication across SC	0.71	
(ξ_3) Supply Chain Range [RGE] (Standardized Cronbach's α = 0.566)			
X_{C11}	Extent to which supplier lead time can be expedited/changed	0.26	0.564
X_{C12}	Number of customer delivery frequencies used	0.31	
X_{C13}	Number of items handled by each distribution facility, on average	0.29	
X_{C14}	Range of volume over which distribution can operate cost effectively	0.45	
X_{C15}	Range of production volumes over which mfg can operate cost effectively	0.51	
X_{C16}	Number of products that each mfg facility, on average, can produce	0.41	
X_{C17}	Range of production capacity across which manufacturing can adjust	0.52	
(ξ_4) Supply Chain Cost Adaptability [AdapC] (Standardized Cronbach's α = 0.708)			
X_{D18}	Change delivery times of order placed with suppliers	0.35	0.718
X_{D19}	Alter delivery schedules to meet changing customer requirements	0.36	
X_{D20}	Change production volume capacity when necessary	0.76	
X_{D21}	Accommodate changes in production mix as required	0.80	
X_{D22}	Reduce manufacturing throughput times to satisfy customer delivery	0.58	
(ξ_5) Supply Chain Time Adaptability [AdapT] (Standardized Cronbach's α = 0.707)			
X_{E23}	Change delivery times of order placed with suppliers	0.32	0.700
X_{E24}	Alter delivery schedules to meet changing customer requirements	0.27	
X_{E25}	Change production volume capacity when necessary	0.78	
X_{E26}	Accommodate changes in production mix as required	0.81	
X_{E27}	Reduce manufacturing throughput times to satisfy customer delivery	0.57	
(η_6) Supply Chain Agility [SCA] (Standardized Cronbach's α = 0.797)			
Y_{F28}	Reduce manufacturing lead time	0.66	0.792
Y_{F29}	Reduce product development cycle time	0.48	
Y_{F30}	Increase level of customization	0.58	
Y_{F31}	Adjust worldwide delivery capacity / capability	0.43	
Y_{F32}	Improve level of customer service	0.58	
Y_{F33}	Improve delivery reliability	0.69	
Y_{F34}	Improve responsiveness to changing market needs	0.71	
(η_7) Firm Performance [Perf] (Standardized Cronbach's α = 0.809)			
Y_{G35}	Return on global assets	0.80	0.792
Y_{G36}	Global market share	0.62	
Y_{G37}	Profit margins (%)	0.75	
Y_{G38}	Total worldwide sales ($) / Global number of employees	0.62	

Notes: All measured variables are significant at α = 5%.
Four error covariance terms (X_{A4}-X_{A5}), (X_{E24}-X_{E27}), (Y_{F32}-Y_{F33}), and (Y_{G36}-Y_{G38}) were added.

In structural equation modeling, there is no single fit index that can absolutely identify a correct model given the sample data [30][32]. Many goodness-of-fit criteria have been formulated to assess an acceptable model fit. The model argues for the plausibility of the postulated relations among the variables if the model fit is adequate, otherwise, the tenability of the relationship is rejected [28]. A list of the various model fit indices and acceptable cut-off criteria can be found in [28][29][30][31][32]. While multiple fit criteria has been suggested for assessing model fit, [33] suggested that the comparative fit index (CFI) and normed fit index (NFI) are the preferred measures. However, the ratio of χ^2 over degrees of freedom has been widely used in recent structural equation modeling research [32].

Table 1 also shows that the Cronbach's α values of all the measurement models are larger than 0.70, except for the *supply chain range* measurement model. However, given the exploratory nature of this study and the small sample size, the scales can be considered sufficiently reliable [34]. Critics argued that Cronbach's α, which is used to test the reliability of a measure based on internal consistency, does not adequately estimate errors caused by factors external to an instrument such as differences in testing situations and respondents over time. In the context of structural equation modeling, it has been recommended that composite reliability of greater than 0.60 be used since they are more parsimonious than Cronbach's α [35]. Again, composite reliability in Table 1 shows that the statistics satisfactorily meet the requirement, except for the *supply chain range* model that marginally missed the 0.60 cut-off point. However, taken together, the model fit statistics, Cronbach's α and the composite reliability statistics suggest that all constructs are sufficiently reliable.

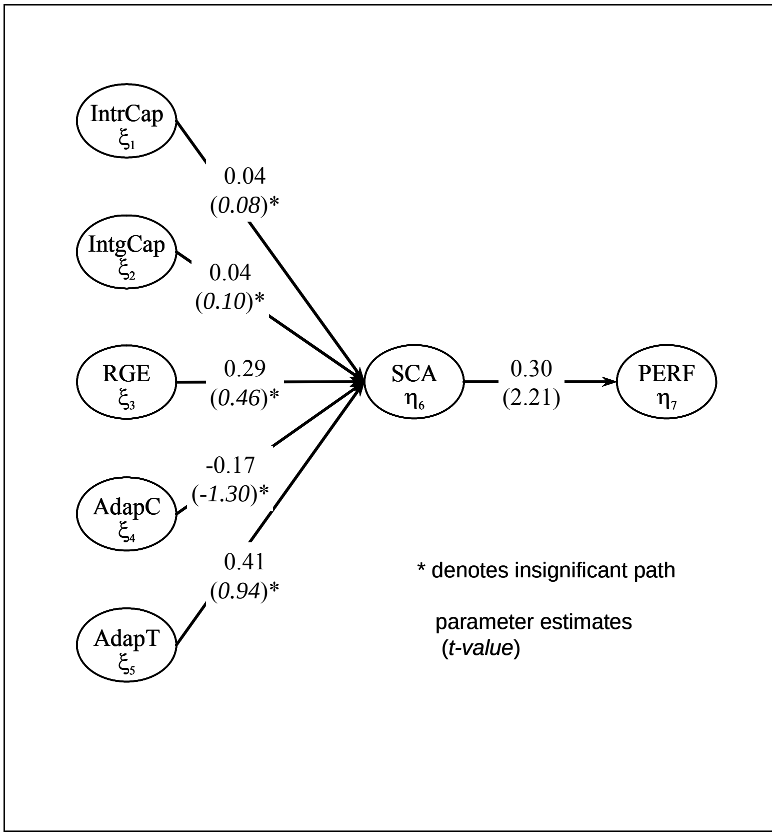
Table 2 presents a list of model fit statistics for the measurement models. Not only was the highest χ^2 to degrees of freedom ratio for the internal capability model (χ^2/df = 2.230) well below the generally acceptable level of 3, all the p-values statistics were statistically insignificant (α = 5%). Moreover, the model ECVI, AIC, and CAIC statistics were close to or exceeded that of the respective saturated models, suggesting excellent model fit. In most cases, values for other commonly used measures of model fit, such as NFI, NNFI, CFI, GFI and AGFI were above the recommended value of 0.90. The standardized factor loadings (Table 1), model fit indices (Table 2), and observed residuals all suggested that the measurement models fit the sample data well, and the parameter values for individual indicators were statistically significant and different from zero. The last column of Table 2 shows the fit indices of the confirmatory factor analysis (CFA) of all the seven measurement models analyzed simultaneously. Again, the CFA exhibits satisfactory fit indices.

Table 2: Fit Statistics - Measurement Models and CFA

GOODNESS-OF-FIT STATISTICS	ACCEPTABLE LEVEL	MEASUREMENT MODELS							CFA
		IntrCap (ξ_1)	IntgCap (ξ_2)	RGE (ξ_3)	AdapC (ξ_4)	AdapT (ξ_5)	SCA (η_6)	Perf (η_7)	
χ^2		8.92	1.72	18.63	6.59	2.15	14.29	1.67	821.00
Degrees of freedom		4	5	14	5	4	13	1	640
χ^2/df	≤ 3.0	2.230	0.344	1.331	1.318	0.538	1.099	1.670	1.283
χ^2 p-value	Non significant	0.063	0.887	0.179	0.253	0.708	0.353	0.197	0.000
RMSEA	≤ 0.05	0.096	0.000	0.050	0.049	0.000	0.027	0.071	0.046
p-value (RMSEA<.05)	≥ 0.50	0.15	0.94	0.45	0.43	0.81	0.64	0.27	0.75
ECVI	Compares to alternative models	0.23	0.19	0.35	0.20	0.20	0.33	0.15	7.69
Saturated ECVI		0.23	0.23	0.42	0.23	0.23	0.42	0.15	11.14
Independence ECVI		2.00	2.88	0.76	1.31	1.34	3.10	1.67	29.22
Independence AIC	Compares to alternative models	266.29	382.62	100.52	174.83	178.36	411.96	222.12	3886.4
Model AIC		30.92	21.72	46.63	26.59	24.15	44.29	19.67	1023.0
Saturated AIC		30.00	30.00	56.00	30.00	30.00	56.00	20.00	1482.0
Independence CAIC	Compares to alternative models	285.78	402.11	127.81	194.32	197.84	439.24	237.71	4034.5
Model CAIC		73.80	60.70	101.20	65.57	67.03	102.76	54.75	1416.7
Saturated CAIC		88.47	88.47	165.14	88.47	88.47	165.14	58.98	4370.3
NFI	≥ 0.90	0.96	1.00	0.79	0.96	0.99	0.97	0.99	0.76
NNFI	≥ 0.90	0.95	1.02	0.91	0.98	1.03	1.00	0.98	0.90
CFI	≥ 0.90	0.98	1.00	0.94	0.99	1.00	1.00	1.00	0.91
IFI	Value close to 1	0.98	1.01	0.95	0.99	1.01	1.00	1.00	0.91
RFI	Value close to 1	0.91	0.99	0.69	0.92	0.97	0.94	0.95	0.73
RMR	-	0.052	0.016	0.067	0.045	0.028	0.036	0.016	0.086
Standardized RMR	≤ 0.05	0.039	0.015	0.060	0.046	0.030	0.042	0.015	0.082
GFI	≥ 0.90	0.97	0.99	0.96	0.98	0.99	0.97	0.99	0.75
AGFI	≥ 0.80	0.90	0.98	0.92	0.94	0.98	0.94	0.94	0.72

5.2 Analysis of the Direct Effect Supply Chain Agility Structural Equation Model

Based on the results of the measurement models, the direct effect supply chain agility structural model was analyzed using the maximum likelihood estimation method. Initial analysis of the structural model revealed that only one of the unidirectional structural paths was statistically significant ($\beta_{7,6}$, Figure 3). While some fit statistics were acceptable, others failed to meet the minimum suggested values. The model suggested that a firm's *internal IT capability*, *IT integration capability*, *supply chain range*, *cost adaptability* and *time adaptability* have no impact on supply chain agility, but *supply chain agility* positively affects *firm performance*. A closer examination of the measurement models suggests that the large measurement errors for some of the indicators may indicate that the constructs are measuring a second-order factor [30].



GOODNESS OF FIT STATISTICS	
χ^2/df	1.277
χ^2 p-value	0.000
RMSEA	0.046
p-value (RMSEA<.05)	0.78
ECVI	7.64
Saturated ECVI	11.14
Independence ECVI	29.22
Independence AIC	3886.39
Model AIC	1015.69
Saturated AIC	1482.00
Independence CAIC	4034.51
Model CAIC	1389.89
Saturated CAIC	4370.30
NFI	0.76
NNFI	0.90
PNFI	0.69
CFI	0.91
IFI	0.91
RFI	0.73
RMR	0.089
Standardized RMR	0.084
GFI	0.75
AGFI	0.72
PGFI	0.66

Figure 3: Direct Effect Supply Chain Agility Structural Equation Model and Fit Indices

5.3 Analysis of the Second-Order Supply Chain Agility Structural Model

Based on the premise that large measurement errors indicate the constructs are measuring a second-order factor [30], we investigated a second-order supply chain agility model (Figure 4). We argue that *information technology capability* (ITC) is a second-order construct consisting of a firm's *internal* (IntrCap) and *integration* (IntgCap) capability. This is consistent with the assertion that information technology helps a firm gather, store and process useful information used to make strategic decisions [14]. Supply chain flexibility literature shows that a firm's flexibility is a measure of its range and adaptability [13]. Using this argument, we contend that a firm's *supply chain flexibility* (SCF) can be measured by its *range* (RGE), *cost* (AdapC) and *time* (AdapT) adaptabilities. Our second-order supply chain agility model argues that a firm's *information technology capability* (ITC) is measured by its *internal* and *integration* IT capability, whereas its *flexibility* is measured by *range*, *cost* and *time* adaptability. Instead of affecting supply chain agility directly, each of the measurement models affects agility through a second-order construct (i.e., through information technology capability or supply chain flexibility).

Figure 5 shows the results of the *information technology* and the *supply chain flexibility* second-order models. Both the models were checked to ensure the parameter estimates exhibited the correct sign and size and were consistent with the underlying theory. All parameters shown were statistically significant at α = 5% and most of the fit indices (ITC: χ^2/df =

1.129, χ^2 p-value = 0.281, RMSEA = 0.031, NFI = 0.97, NNFI = 0.99, CFI = 1.00; SCF: χ^2/df = 1.236, χ^2 p-value = 0.050, RMSEA = 0.042, NFI = 0.84, NNFI = 0.94, CFI = 0.96) indicate the sample data fit the hypothesized second-order models well. The results support the second-order constructs and underlying theory. That is, a firm's information technology capability can be measured by its *internal IT capability* and *IT integration capability*, whereas *supply chain flexibility* is derived from *supply chain range*, *cost adaptability,* and *time adaptability*.

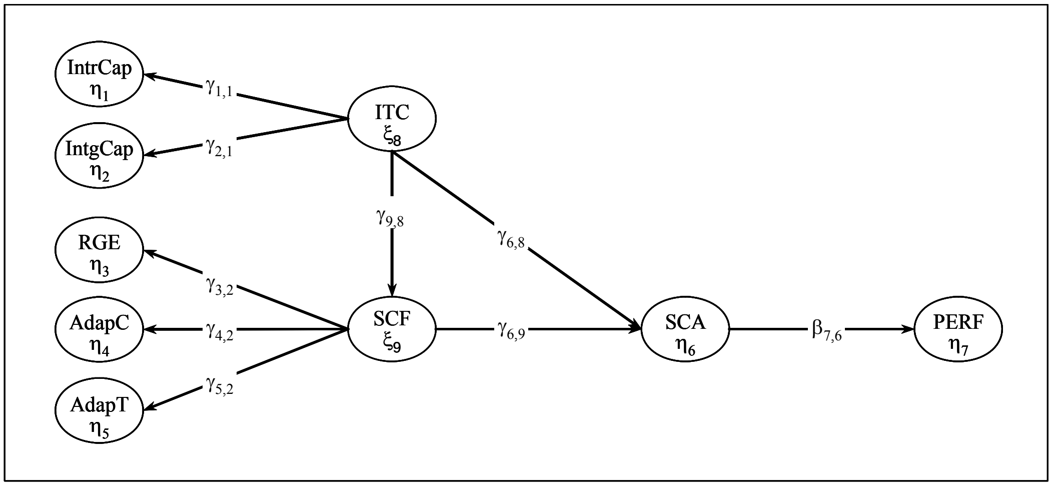


Figure 4: Second-Order Supply Chain Agility Structural Equation Model

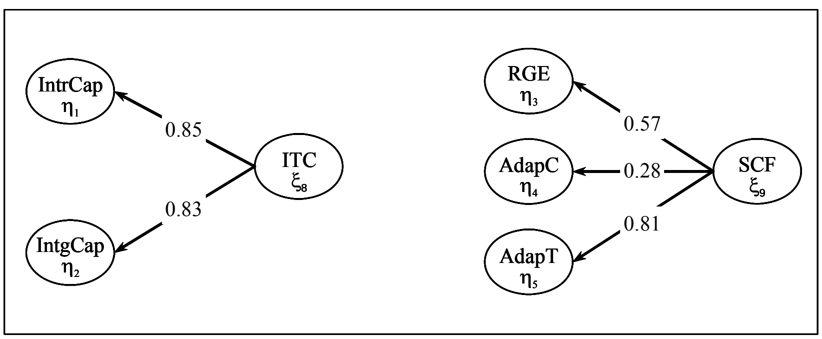


Figure 5: Second-Order Information Technology and Supply Chain Flexibility Models

Finally, the second-order *supply chain agility* structural equation model was evaluated (Figure 6). All structural paths, except the influence of *information technology* on *supply chain agility*, were statistically significant. Model fits indices for the second-order *supply chain agility* model were also satisfactory. Most distinctly, the χ/df statistic of 1.070 is notably less than the generally accepted minimum of 2.0. Our analysis suggests that *information technology capability* does not affect *supply chain agility* directly, but through *supply chain flexibility*. *Supply chain agility* mediates the impact of *supply chain flexibility* on *firm performance*. More importantly, our analysis shows that *internal* and *integration IT capability*, *supply chain range*, *cost adaptability*, and *time adaptability*, do not directly affect a firm's supply chain agility. Instead, a firm's *internal* and *integration IT capability* collectively measures its overall *information technology capability*. Additionally, a firm's *supply chain range*, *cost adaptability,* and *time adaptability* collectively measures its overall supply chain flexibility in responding to the rapidly changing marketplace.

6. Discussion and Conclusion

This study empirically examines the determinants of supply chain agility, and its impact on firm performance. We also tested the impact of information technology capability and supply chain flexibility on supply chain agility. Despite the attempt to relate flexibility to agility, researchers have not been successful in conclusively establishing the relationships between these two complex constructs. We believe we might have discovered a missing link in solving the mystery; that is, past research ignored the possibility that supply chain flexibility is indeed a second-order construct measuring a firm's range, and cost and time adaptability, whereas information technology capability is an entirely different construct measuring a firm's internal and integration capability. Each of these five measurement models does not affect agility directly, but though two second-order constructs.

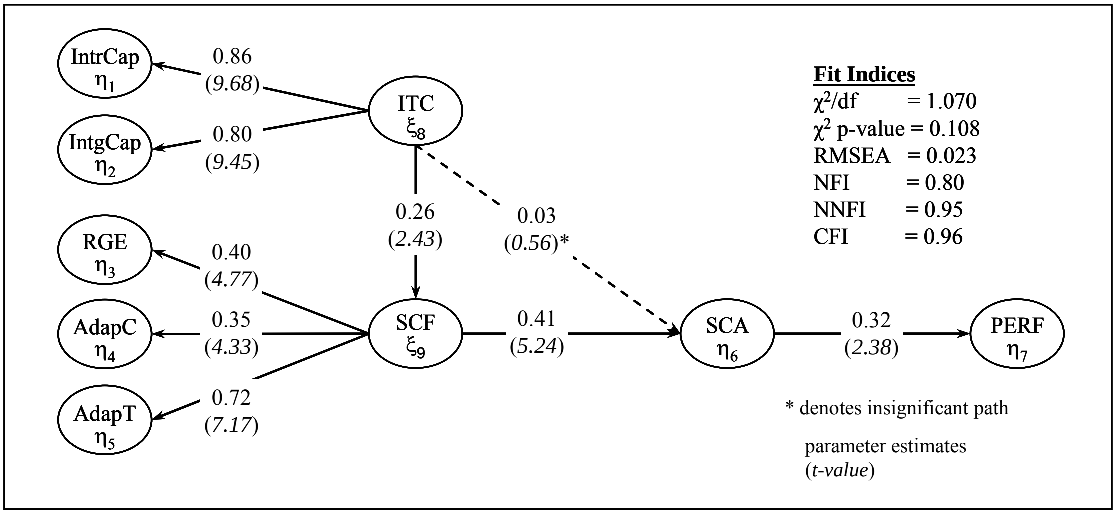


Figure 6: Second-Order Supply Chain Agility Structural Equation Model

The findings are significant and provide useful guidelines for managers who intend to build an agile corporation that is capable of rapidly responding to the changing global marketplace efficiently. Savvy managers must focus on their internal and integration IT capability concurrently to enhance information technology capability. Similarly, they must also focus on their supply chain range, cost adaptability and time adaptability in tandem to improve supply chain flexibility. Competency in supply chain flexibility cannot be over-emphasized because our results show that proficiency in information technology does not affect supply chain agility or firm performance directly. Instead, information technology capability affects supply chain agility and performance via supply chain flexibility. This may be one of the reasons why many ERP implementations since the Y2K scramble remain vastly under-utilized. Consequently, firms struggle to justify their investment and find ways to better utilize their ERP systems [36]. Intricate business process reengineering challenges arise when business processes are adapted to the software, a common scenario in ERP implementation. Without a throughout knowledge of how complex information technology interacts with other capability of the firms, it is difficult to fully reap the benefits of the investment in information technology. Our research shows that without supply chain flexibility, implementing information technology will not improve firm performance.

The second major finding of our research is that supply chain flexibility impacts supply chain agility, and supply chain agility positively influences performance. Supply chain agility is a mediator of supply chain flexibility to firm performance. Thus, it is imperative that firms be agile and flexible to improve performance. The managerial implication is that any effort to improve information technology capability and supply chain flexibility is likely to be futile if the firm lacks supply chain agility. Supply chain agility is the mediator of these two constructs on firm performance.

The research is not without its limitations. The model does not consider performance from multiple perspectives. For instance, it does not consider variables such as market structure from the industrial organization literature. The use of longitudinal data would also have been useful to study how changes in certain variables affect performance. Future research also needs to explore additional facets of supply chain flexibility and agility.

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