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The Mediating Effect of Agility: IT's Impact on Firm Performance among U.S. Manufacturing Firms

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Abstract

This study investigates the mechanism through which IT affects performance using mediation analysis to determine if agility, the ability to sense and respond to changes in the market, explains "how" or "why" IT affects performance. The results of the mediation analysis are based on data collected from survey responses from 193 U.S. manufacturing firms. Agility as a mediator was investigated using three testing methods: causal steps strategy, product of coefficients, and bootstrapping. Causal steps strategy tested the direct effects using regression analysis, the product of coefficients tested the statistical significance of the mediation effects assuming the coefficients were normally distributed, and bootstrapping tested the significance of the mediation effects without assuming they were normally distributed by creating a distribution of the product of coefficients. The mediation effect using all three tests was demonstrated, providing a robust confirmation that agility mediates the impacts of IT on firm performance.

Keywords: Agility; Information technology; Mediating variable; Firm performance

Introduction

Global competition and the accelerating pace of technological and market changes make the ability to sense and respond to market changes critical to business [1-3], and especially important for firms that rely on extended, often global, supply chains to bring products to market [4,5]. The ability to sense and respond is captured in the concept of 'agility' [5,6]. Agile firms are firms that adapt to and perform well in today's rapidly changing markets and technological environments [7-9].

Firms use many tools to help them sense and respond to market changes ahead of rivals, including market and consumer research conducted in-house or purchased from consulting firms; demographics analysis; trends analysis; scenario building; and economic forecasting models among others. Recent advances in information technologies also have the potential to significantly increase firm agility [3,10]. However, there are few empirical studies showing that IT enhances agility or, more importantly, that agility is the mechanism through which IT affects firm performance. This study focuses on identifying the mechanisms through which IT affects firm performance, which is essential to effective IT investment, design, and implementation.

In previous empirical research, we found that IT enhanced both supply chain agility (β=0.725) and firm performance (β=0.392) [11]. Specifically, the study found that IT enhanced both the sense (β=0.633) and respond (β=0.786) dimensions of supply chain agility, and improved firms' financial performance measured by sales, market share, and profitability (β=0.633), and operational performance measured by speed to market and customer satisfaction (β=0.440). All regression coefficients had p values less than .01.

These findings show that IT affects both agility and performance, but do not demonstrate how IT affects performance. Mediation analysis is used when the researcher is interested in "how" or "why" one variable affects another in order to increase the understanding of the (black box) relationships among variables [12]. This is valuable to formulating actions to enhance the relationships in ways that contribute to the achievement of ultimate goals. Mediation analysis is used in this study to determine if agility, the ability to sense and respond to changes in the market, explains "how" or "why" IT affects firm performance.

Mediation model

The mediation model was developed to test if agility is the operational mechanism through which IT affects firm performance (Figure 1). It is based on the three constructs: IT Use, Agility, and Firm Performance. IT is the independent variable, firm performance the dependent variable, and agility, the mediating variable. The components used to measure each construct in Figure 1 is shown in Table 1.

Causal steps strategy, product of coefficients, and bootstrapping methodologies are used to test whether agility mediates IT's impact on firm performance. The direct effects of IT on firm performance are first tested using regression analysis following the causal steps strategy [13].

Three regressions are run:

(1) Firm performance on IT

(2) The mediating variable agility on IT

(3) Firm performance on IT and the mediating variable agility.

The hypothesized mediating role of agility is confirmed if all coefficients of the three regressions are statistically significant at

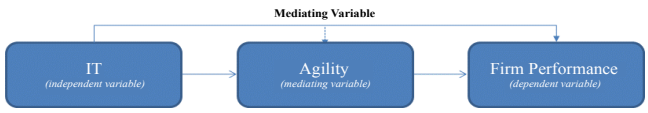

Figure 1: Mediation Model.

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Construct	Operationalized	Scale
IT Use	IT use to sense market changes in customer demand IT use to sense market changes in competitor actions IT use to sense market changes in technology trends IT use to respond by developing coordinated plan with supply chain IT use to respond by executing a coordinated plan with supply chain	1 Not at all 2 Small extent 3 Moderate extent 4 Large extent 5 Very large extent
Agility	Information quality in terms of adequacy Information quality in terms of accuracy Information quality in terms of accessibility Information quality in terms of timeliness Develop coordinated plan with supply chain in terms of timeliness Develop coordinated plan with supply chain in terms of cost Develop coordinated plan in terms of quality/effectiveness Execute coordinated plan with supply chain in terms of timeliness Execute coordinated plan with supply chain in terms of cost Execute coordinated plan with supply chain in terms of quality/effectiveness	1 Not at all 2 Small extent 3 Moderate extent 4 Large extent 5 Very large extent
Firm Performance	Sales Market share Profitability Speed to market Customer service	1 Very negative 2 Somewhat negative 3 No effect 4 Somewhat positive 5 Very positive

Note: Constructs measured along a 5-point Likert scale (1=low, 5=high)

Table 1: Components of IT, Agility, and Firm Performance Constructs.

the 95% level; and if the hypothesized mediator, agility, reduces the effect of IT on firm performance. This is determined by comparing the coefficients of regression for IT in the first and third regression equations. Mediation is demonstrated if the coefficient of regression for IT is reduced in the third equation where the mediation variable, agility, is introduced.

However, even if all three regressions are statistically significant at the 95% level, and the IT coefficient of regression is reduced when agility is introduced into the equation, the statistical significance of the mediation effect is not known. Mediation is strongly suggested but it is not statistically tested. The product of coefficients test is therefore used to determine the significance of the mediating effect of agility. The mediation effect is the product of the two indirect effects in Figure 1. It is the product of the impact of IT (independent variable) on agility (mediating variable) and the impact of agility (mediating variable) on firm performance (dependent variable). Dividing this mediating effect by its standard error yields a Z score for the mediation effect that can be compared with a standard normal distribution. Thus, if the Z score is greater than 1.96, the mediation effect is statistically significant at the .05 level [14,15].

The product of coefficients test, however, is limited by its assumption that the product of the indirect effects is distributed normally. Since the distribution of the product of two variables is unlikely to be distributed normally despite a large sample size, bootstrapping is used as the principal test of the significance of the mediation effect. Bootstrapping is a nonparametric test that does not require the indirect effect to be distributed normally. Bootstrapping entails running 5,000 samples of the original data to generate an empirical distribution of the indirect effects [16]. It then calculates the regression coefficients, standard errors, and percentage confidence intervals (95% level) for this distribution. The indirect effect is statistically significant if zero is not within the range of the confidence interval. Confirmation of the mediating relationship by all three tests, would provide confidence that agility mediates IT's impact on firm performance.

Results of the mediation analysis

The results of the mediation analysis are based on responses to a survey mailed to 1,445 individuals with supply chain responsibilities at large U.S. manufacturing firms. A total of 193 usable responses were received. Table 2 shows the number of responses by the respondent's position, organizational, and geographical scope of responsibilities in the firm, and by the size of the firm measured by global sales.

Over 85% of the respondents held positions of Director or higher within their firms; 70% had global responsibilities; over half had corporate–wide responsibilities; and a third had responsibilities for multiple business units within their firms. Nearly two-thirds of the firms had global sales in excess of $2 billion; one quarter had sales greater than $10 billion.

The survey instrument was tested for the reliability and validity of the three constructs: IT Use (5 items), Agility (10 items), and Firm Performance (5 items) using Confirmatory Factor Analysis and Cronbach's alpha test. The results of reliability and validity testing indicate that all three constructs have both high reliability and high validity (Table 3).

The two-item sub construct of operational measures (FP6) in the Firm Performance (FP1) construct had Cronbach's alpha of 0.671, which represents acceptable reliability. Since Cronbach's alpha can underestimate reliability with scales of five items or less, the Spearman-Brown prophesy formula may be used to adjust for alpha values [18].

	N	%
Sample	193	100
Title/Position		
Manager	15	7.8*
Senior Manager	12	6.2
Director	116	60.1
Vice President	32	16.5
Senior Vice President	6	3.1
CIO	1	0.5
General Manager	5	2.6
Other	6	3.1
Geographic Area of Responsibility		
Global	136	70.5*
National	34	17.6
Regional	23	11.9
Area of Firm Supported		
Corporation (corporate-wide)	107	55.4*
Multiple Business Units / Segments	64	33.2
Single Business Unit / Segment	22	11.4
Global Sales		
$0 - $700 million	32	16.6*
>$700 million to $1 billion	16	8.3
>$1 billion to $1.5 billion	12	6.2
>$1.5 billion to $2 billion	9	4.7
>$2 billion to $3 billion	26	13.5
>$3 billion to $5 billion	29	15.0
>$5 billion to $10 billion	20	10.4
Greater than $10 billion	49	25.4

Note: * $p < .05$ Chi-square test

Table 2: Respondent and Firm Characteristics.

Construct	Sub Contruct	Item	Mean	SD	α	Factor
IT Use			2.768	0.787	0.830	
IT1	IT2		2.751	0.869	0.793	0.765
		IT3	3.093	1.095		0.659
		IT4	2.518	0.969		0.807
		IT5		1.032		0.809
			2.643	0.944	0.784	0.798
	IT6	IT7	2.793	0.963		0.899
		IT8	2.679	1.037		0.872
			2.907			
Agility			2.964	0.822	0.945	
AG1	AG2		3.168	0.892	0.927	0.786
		AG3	2.990	0.968		0.888
		AG4	3.124	0.955		0.881
		AG5	3.275	1.022		0.824
		AG6	3.285	0.993		0.832
	AG7	AG8	2.827	0.916	0.952	0.867
		AG9	2.829	1.029		0.816
		AG10	2.668	1.007		0.821
		AG11	2.814	0.966		0.897
		AG12	2.969	1.045		0.951
		AG13	2.777	1.044		0.840
			2.907	1.032		0.905
			3.665	0.594		
	FP2		3.649	0.619	0.861	0.885
		FP3	3.710	0.691	0.822	0.805
Firm Performance		FP4	3.523	0.744		0.780
FP1		FP5	3.715	0.727		0.757
	FP6		3.689	0.669		1.085
		FP7	3.580	0.813	0.671	0.666
		FP8	3.798	0.726		0.764

Note: Mean/SD of constructs measured along a 5-point Likert scale (1=low, 5=high). N = 193. α = Cronbach's alpha test of internal consistency. Tests of model fit for confirmatory factor analysis (CFA): $\chi 2 = 299.998$, df = 152, $p < .001$; RMSEA (90% CI) = .071 (.059-.083); CFI = .954. All factor loadings are significant at $p<.05$. Refer to Table 4 for the coding of the variables used in this table

Table 3: Reliability and Validity of IT Use (IT), Agility (AG), and Firm Performance (FP) Constructs.

As such, the alpha value (α=0.671) for the operational measure sub construct (FP6) was adjusted to 0.803 using the Spearman-Brown prophesy formula:

$\rho^*_{xx'} = \frac{2\rho_{xx'}}{1+\rho_{xx'}}$ where $\rho^*_{xx'}$ =predicted reliability and $\rho_{xx'}$ = current reliability.

The results of the mediation analysis are presented in Tables 5 and 6. Significance was determined by Type I error rates less than p=0.05 (two-tailed tests). Table 5 presents the results of the three regressions for the mediation analysis. As shown, a significant relationship was found between IT and firm performance, IT and agility, and between IT, agility and firm performance as p values were less than .05 for all three regressions. Critically, the coefficient of regression was lower for IT in the third equation (β=0.229), than in the first equation (β=0.403). That is, the impact of IT on firm performance was reduced when the mediation variable, agility, was introduced into the equation. This suggests that agility mediates the impact of IT on performance. However, while the significance of the mediation effect is strongly suggested, it is not statistically tested.

The final step in confirming that agility mediates IT's impact on firm performance was conducted using the nonparametric bootstrapping test [16]. Five thousand samples were run in this re-sampling procedure to estimate the empirical distribution of the indirect effects, and their statistical significance. The regression coefficients, standard errors, and the percentile confidence intervals (95% level) were calculated for the estimated empirical distribution of indirect effects. The confidence interval, as shown in Table 6, was 0.082 to 0.266. Since zero is not within the confidence interval, the indirect effect is statistically significant at the 95% level, confirming that IT impacts firm performance through the mediator, agility.

In summary, the mediating role of agility on IT's impact on firm performance was investigated using three testing methods. The results of the causal steps strategy suggested a mediation effect. The product of coefficients test confirmed the mediation effect, assuming a normal distribution. Finally, bootstrapping confirmed the mediation effect without assuming the product of the indirect effects is normally distributed. Confirmation of the mediation effect by all three tests provides a robust confirmation that agility mediates the impacts of IT on firm performance.

Discussion and Conclusions

This paper extends prior analyses of the impacts of IT on agility and firm performance by demonstrating that agility is the mechanism through which IT affects both financial and operating performance. These findings have important implications for firms contemplating investments in IT. To optimize these investments, firms should focus on employing IT to improve the sense and respond dimensions of agility because both of these lead directly to improved firm performance.

These findings are especially relevant to the selection of specific technologies for coordinating operations throughout the supply chain. ERP systems are widely accepted as critical technologies to coordinate supply chain activities. Future investments, either as expansions of or as alternatives to the current ERP system, can improve firm performance by enhancing supply chain agility. Specifically, IT deployments that improve the quality of information flows throughout the supply chain (improve the adequacy, accuracy, accessibility, and timeliness of information flows), and that increase the firm's ability to develop and execute coordinated plans throughout the supply chain (in terms of quality, cost, and timeliness) are expected to contribute to improved

financial and operating performance. This finding is essential to IT professionals concerned with how IT adds value to the firm [3].

The authors are aware of only one other empirical study, limited to the automotive industry, of the mediating role of agility on IT's impact on firm performance Vickery et al. [18].

Although the measures used for evaluating agility and firm performance were not identical to this study, Vickery et a [18]l. also found that IT impacts firm performance through the mediator agility. The findings of this study support Vickery et al. [18], and, more importantly, generalize these findings beyond a single industry.

Future Research and Limitations

The findings of this study provide new insights into IT's impact on supply chain agility and firm performance that can serve as both a theoretical and empirical base for future research. This study also demonstrates the application of a statistical technique, mediation analysis that can be applied in future research to provide greater understanding of the causal relationships among IT, agility, other potential mediators, and firm performance. Additional insights into the effective deployment of IT could be produced by investigating the conditions under which IT deployments have their greatest impacts on the coordination of supply chain operations. For example, what specific functional areas and processes (product development, procurement, production, logistics, and service) would benefit most from the application of IT systems.

This study focused on large U.S. manufacturers, which may restrict the applicability of the findings to smaller firms, non-U.S. firms, and service providers. Almost 65 percent of the firms participating in this study had annual sales in excess of $2 billion, and over 35 percent of the firms had annual sales in excess of $5 billion. Since this study was limited to manufacturers, the results should be applied with caution to service firms. Finally, the study focused on U.S. firms, which although they operate globally, may not operate under market, supply chain, or technological conditions similar to foreign firms. Therefore, generalizing the results to firms outside the U.S. should also be done with caution. Consequently, extending this research to smaller firms, service firms, and non-U.S. firms are fruitful areas for future research.

Code	Composition of Code	Item
Constructs:		
IT Use	Sum of IT3-	**IT Use Construct**
IT1	IT5, IT7-IT8	**Sub Construct: Sense**
IT2	Sum of IT3,	IT use to sense market changes in customer
IT3	IT4, IT5	demand
IT4		IT use to sense market changes in competitor
IT5		actions
IT6		IT use to sense market changes in technology
IT7	Sum of IT7,	trends
IT8	IT8	**Sub Construct: Respond**
		IT use to respond by developing coordinated plan with supply chain
		IT use to respond by executing coordinated plan with supply chain
Agility		
AG1	Sum of AG3-	**Agility Construct**
AG2	AG6, AG8-	**Sub Construct: Sense**
AG3	AG13	Information quality in terms of adequacy
AG4	Sum of AG3,	Information quality in terms of accuracy
AG5	AG4, AG5,	Information quality in terms of accessibility
AG6	AG6	Information quality in terms of timeliness
AG7		**Sub Construct: Respond**
AG8		Develop coordinated plan with supply chain in terms of timeliness
AG9		
AG10		Develop coordinated plan with supply chain in terms of cost
AG11	Sum of AG8,	
AG12	AG9, AG10,	Develop coordinated plan in terms of quality/
AG13	AG11, AG12,	effectiveness
	AG13	Execute coordinated plan with supply chain in terms of timeliness
		Execute coordinated plan with supply chain in terms of cost
		Execute coordinated plan with supply chain in terms of quality/effectiveness
Firm Performance		
FP1	Sum of FP3-	**Firm Performance Construct**
FP2	FP5, FP7-FP8	**Sub Construct: Financial Measures**
FP3	Sum of FP3,	Sales
FP4	FP4, FP5	Market share
FP5		Profitability
FP6		**Sub Construct: Operational Measures**
FP7		Speed to market
FP8	Sum of FP7, FP8	Customer service

Table 4: Nomenclature of Coding for Hypotheses Testing Results.

Equation	DV	IV	B	SE	*t*	*p**	R^2*(adj)*
1	FP1	IT1	0.403	0.046	8.73	0.000	28.1%
2	AG1	IT1	0.725	0.054	13.34	0.000	48.0%
3	FP1	IT1	0.229	0.062	3.71	0.000	33.5%
		AG1	0.240	0.059	4.06	0.000	

Note: *Regression coefficient at $p<0.01$ level. IT1 = IT, AG1 = Agility, FP1 = Firm Performance

Table 5: Regression Analysis of Casual Steps Strategy.

	Product of Coefficients				Bootstrapping	
	Point Estimate	SE	Z	P-Value	95% CI Lower	95% CI Upper
	Direct Effects					
IT	0.229	0.059	3.887	0.000*	0.113	0.326
AG	0.240	0.063	3.818	0.000*	0.117	0.363
	Indirect Effects					
AG	0.174	0.047	3.703	0.000*	0.082	0.266

Note: 5,000 bootstrap samples. CI = confidence Interval. FP = Firm Performance; IT = Information Technology; AG = Agility. *p<.05; Z>1.96. Direct effects: dependent variable = FP (firm performance), independent variables IT and AG (Agility)

Table 6: Analysis of Product of Coefficients and Bootstrapping.

This study focused on large U.S. manufacturers, which may restrict the applicability of the findings to smaller firms, non-U.S. firms, and service providers. Almost 65 percent of the firms participating in this study had annual sales in excess of $2 billion, and over 35 percent of the firms had annual sales in excess of $5 billion. Since this study was limited to manufacturers, the results should be applied with caution to service firms. Finally, the study focused on U.S. firms, which although they operate globally, may not operate under market, supply chain, or technological conditions similar to foreign firms. Therefore, generalizing the results to firms outside the U.S. should also be done with caution. Consequently, extending this research to smaller firms, service firms, and non-U.S. firms are fruitful areas for future research.

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