

Higher Order vs. Lower Order Complementarities: Assessment of their Relative Impact on Organizational Agility

Pankaj Setia, Shawnee K. Vickery, V. Sambamurthy and Cornelia Droge (Michigan State University)

Introduction

The business value research, after the initial findings of missing impact of IT systems, has focused on alternate mechanisms that affect performance of IT systems (Loveman 1994, Barua and Mukhopadhyay 2000, Brynjoffsson and Hitt 1996). **Amongst** the various processes that affect the value realization of IT, a critical factor is related to the complementary processes and mechanisms that may interact with IT systems (Barua and Mukhopadhyay 2000, Milgrom and Roberts 1990, 1995, Barua and Whinston 1998). This complementary interaction has been identified as the missing process that led to the non-realization of the value, or its measurement, in the earlier productivity studies.

The existing business value literature has found the presence of these complementary effects across the various IT applications. Complementarities of IT systems, for example, have been identified in the use of supply chains (Banker et al. 2006) and infrastructure technologies (Zhu and Kraemer 2002). These complementary effects are due to the interaction of IT with another organizational element (as strategy, culture etc.) and hence are bilateral in nature. The argument for this bilateral interaction is the synergistic impact that sets in when IT systems are used in concurrence with the other related organizational initiatives. Milgrom and Roberts (1990) initially proposed this causal synergy in the use of flexible manufacturing systems, and subsequent empirical tests revealed the presence of positive interactions. Parthasarthy and Sethi (1992, 1993), for example, tested the bilateral interaction with various organizational elements as strategy types, structure, shop floor personnel skills, design manufacturing workflows, and project teams and workgroups. These bilateral interactions have also formed the basis of other research studying the complementary effects (Banker et al. 2006).

Lower Order and Higher Order Complementarities

These bilateral interactions of IT with another organizational variable assume the IT impact to be contingent on this variable and are defined in this research as lower order complementarities. Researchers have highlighted the limitations of these lower order interactions. The basic criticism is of the underlying assumption that the two variables interacting in the lower order complementarities are isolated from other organizational practices. Researchers have instead proposed that it is not just the interaction between the two but the synchronization of multiple elements in the work system that contributes to realization of true benefits of IT (Milgrom and Roberts 1995). We define this alignment of IT with multiple organizational practices and initiatives as the higher order complementary effect.

The bilateral impacts are especially seen to be weak in the introduction of IT systems, which are well known to require alignment with the overall business strategies and many other organizational elements. The IT systems often introduce a discontinuity in the organization that calls for an alignment of the overall organizational work culture and routines. Frequently, thus, the firms that successfully introduce IT systems also align many other organizational practices and norms to match with the introduction of the new IT systems. For example, Womack et al. (1991) and Milgrom and Roberts (1990) have documented the paradigm shift from mass production to lean production. Milgrom and Roberts (1995), proposed the presence of and higher order complementarities in these environments: *“Changing only a few of the system elements at a time to their optimal values may not come at all close to achieving all the benefits that are available through a fully coordinated move and may even have negative payoffs. Of course, if those making the choices fail to recognize all the dimensions across which the complementarities operate, then they may fail to make the full range of necessary adaptations with unfortunate results.”* (p.191). Other researchers have similarly suggested higher order complementary effects rather than lower order (bilateral) effects as the means to fully explain the organizational dynamics. Whittington et al. (1999), for example, point, *“The notion of complementarities develops a line of thought in organizational theory that leads through contingency theory to configurational theory”*.

These arguments raise concerns as to which of the two (lower order or higher order) complementarities more accurately explain the processes that underly successful IT use. In this research we explore the relative effect of lower and higher order complementarities on the organizational outcomes. Specifically, we explore: ***Are both the lower and higher order complementarity effects present in organizations, and what is their relative significance?*** We study the flexible manufacturing systems that have been analyzed by Milgrom and Roberts (1990, 1995) in their seminal work that introduced and popularized the notion of complementary effects in IT use. Further, to measure their interaction, the empirical data on organizational variables was collected by surveying CEOs or strategic business unit (SBU) heads of first tier suppliers to the “Big Three” car companies (OEMs) in North America. We next develop the research model and follow it with the discussion of results.

Research Model

Supply chain organizations within today's business firms can no longer be merely efficient (Lee 2004). The rapidly changing business environment calls for the firms' supply chains to sense and respond to the changing business conditions and hence develop the dynamic capabilities for these effects. The superior firms in today's environment develop capabilities to continually respond to the changed market conditions. Agility is such a capability, which is essential for the firms to compete in today's business environment (Lee et al. 2004, Sambamurthy et al. 2003, D'Aveni 1994). For the manufacturing firms, their ability to fulfill the customer orders with speed, reconfigure their products according to the changed customer orders, and lessen their manufacturing time are the key indicators of their sense and respond capabilities. These indicators are thus used as measures of agility of manufacturing firms. This agility of the firms manufacturing operations is studied as the dependent variable in this research.

We assessed the impact on agility of the two lower order complementary interactions of IT - with HR practices and top-level management commitment respectively. Finally, we assessed the three-way interaction between all these three organizational elements to assess the higher order complementary effect on the organizational agility. We next explain these three variables used by us.

Flexible Manufacturing IT systems: The use of flexible manufacturing systems was measured in each of the SBU's by measuring the extent of the use of the CAD, CAM and CIM systems (the IT components of flexible manufacturing systems as highlighted by Parthasarthy and Sethi 1992¹). The key advantage of these IT systems is that they make manufacturing programmable, which in turn leads to timely and hassle-free information transfer across the departments and organizations, helps engineers and craftsmen design and analyze new parts in consultation with their customers and suppliers, marketing staff, and strategic and manufacturing experts, and store prototypes and manufacture parts on a need-to-use basis (Gurbaxani and Whang 1991, Nemetz and Fry 1988). These advantages due to digitization and programmability lead to the creation of organizational capabilities (as agility) that are a source of superior firm performance (Sambamurthy et al. 2003, Barua et al. 2004).

While the introduction of flexible manufacturing systems in the organizations was meant to lead to increased agility of operations, the information systems literature has documented the difficulties in creating the IT impact. In this research we consider their simultaneous implementation with the introduction of two other related organizational factors – human resource initiatives and top-level commitment.

HR Initiatives: While the introduction of IT systems leads to greater flexibility, it also calls for enhanced flexibility in the human resource practices on the shop floor and in the engineering and product development functions (Womack et al. 1991). Milgrom and Roberts associate the flexibility and speed of modern manufacturing methods with cross-trained workers, worker initiatives, and greater freedom to workers. Similarly, other researchers have emphasized the use of employee training and employee empowerment (including employee autonomy and employee impact) (Jayaram and Vickery 1998), and broad job descriptions (Roth et al. 1989). In this research we study the three different human resource initiatives- employee empowerment (employee autonomy and employee impact), extent of job rotation and cross training.

Top Level Management Commitment The alignment of the IT strategy with the overall business objectives has been highlighted as the key success factor for successful use of IT in organizations (Henderson and Venkataraman 1993). The top-level commitment and championing of IS goals has been identified as the key factor for superior assimilation of IT systems within the organizations (Armstrong and Sambamurthy 1999). First, top-level management helps in the implementation of appropriate IS governance structure in the organization. The top-level commitment ensures the establishment of appropriate governance structures (Brown 1999; Applegate et al. 1996). Further, top management commitment ensures the sharing of perspectives, pooling of know-how, and development of shared understanding among different business functions to align the individual interests to common organizational goals (Nahapiet and Ghoshal 1998). In this research, we assess the total top-level commitment to innovation, flexibility and time-based competition and its impact on the use of flexible manufacturing systems.

We test three models to unravel the process by which IT impact occurs on the manufacturing agility. The first model tests higher order complementary effects as the interaction of IT with the other two synergistic organizational elements - HR

¹ While a fourth part of these flexible manufacturing systems are the automatic storage and retrieval systems these include heavy machines and robots that are used to move parts on the shop floor and are not considered as part of our *information technology* construct.

initiatives and top-level commitment (figure 1, model 1). The hypothesized relations is

Hypothesis 1 (Higher Order Complementarities): Multiple interaction between flexible manufacturing IT systems, HR practices and top level management commitment will lead to greater organizational agility.

Two other models test lower order complementarities IT with these HR and top level individually in separate models (see figure1, model 2 and 3). One model proposes for the bilateral interaction of IT with the HR initiatives (employee autonomy, employee impact, broad jobs and cross training) and tests the hypothesis.

Hypothesis 2 (Lower Order Complementarities): Complementary interaction of human resource initiatives with the flexible manufacturing IT systems will lead to greater organizational agility.

The other model studies the interaction of IT with top-level management commitment to flexibility, time based competition and innovation and tests whether

Hypothesis 3(Lower Order Complementarities): Complementary interaction of top-level management commitment with the flexible manufacturing IT systems will lead to greater organizational agility.

 Insert Table 1 and Figure 1 about here

Analysis and Results

The sample consisted of 57 firms with their profiles in table 1. Hypotheses were tested using structural equation modeling, which helps model the latent factors, measurement errors and relations among the latent factors. Analysis of survey data was done using two-step procedure as recommended by Anderson and Gerbing (1988). The confirmatory factor analysis (CFA) was run to test the measurement properties and reliabilities were evaluated using the procedure suggested by Fornell and Larcker (1981) (see table 2). Our results indicate that the multiple synergistic interactions of IT with HR initiatives and top-level mgmt commitment are significant (see table 3 and 4). We also found significant bilateral interactions of IT with top-level management commitment; however, the model with the HR complementarities (model 2) has only weak support (see table 3 and 4).

 Insert Table 2, 3 and 4 about here

The lower order interactions are found to have a weaker effect on the organizational agility as compared with the higher order complementary effects. The interaction of IT with the top level championing is found to be only weakly significant. Also the model with the human resource interaction with IT has average fit and hence only weak empirical support. Compared with these two models the model proposing the higher order complementary effect has a good empirical fit with the data and also the coefficient for this effect is highly significant. The research thus supports the presence of higher order effects and is likely to extend the inquiry of IT impacts beyond the bilateral interactions. More in-depth evaluation of higher order complementary effects would further enrich the understanding of the processes that lead to creation of superior business value through the use of IT systems. This research contributes by presenting the first empirical evidence for such higher order complementary effects.

Figure 1: Research Models

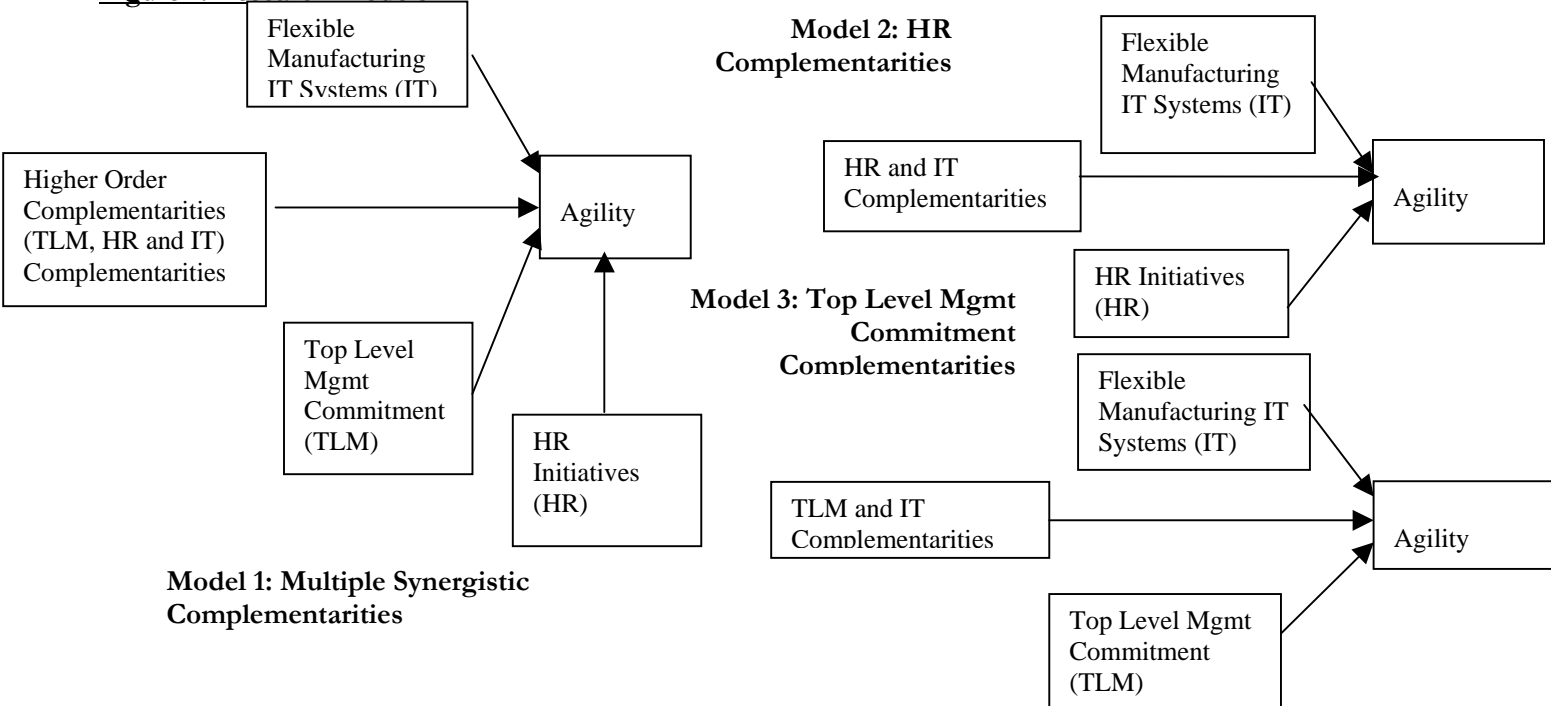


Table 1: Frequency distribution of sales and number of employees

Annual Sales (US \$ Million)	Number of Firms	Percentage
A. Frequency distribution of annual sales		
1-249.99	23	40.3
250-499.99	12	19.3
500-999.99	11	21
1000-1499.99	4	7
1500 and above	3	5.4
Missing data	4	7

B. Frequency distribution of number of employees

Number of Employees	Number of Firms	Percentage
1-1000	17	29.8
1001 - 2000	15	26.3
2001 - 3000	8	14
3001 - 4000	3	5.3
4001 - 5000	5	8.8
Above 5000	7	12.3
Missing Data	2	3.5

Table 3: Construct Reliability, and Item Loadings

Construct	Construct Reliability	Item	Loading (I)
AGILITY	0.76	Delivery Speed	0.81
		Manufacturing Lead Time	0.91
		Responsiveness To Customers	0.37
FLEXIBLE MFG IT SYSTEMS	0.68	Computer-Aided Design (CAD)/Computer Aided Engineering (CAE)	0.47
		Computer-Aided Manufacturing (CAM)	0.85
		Computer Integrated Manufacturing (CIM)	0.6
HR INITIATIVES	0.70	Broad Job	0.42
		Employee Empowerment	0.97
		Cross Training/ Job Rotation	0.54

Note: All the loadings were found to be significant at .05 level
 Top-level management was measured as a summative scale and hence the reliabilities and loadings are not reported.

Table 4: Model Fit Statistics

TEST STATISTIC	HIGHER ORDER COMPLEMENTARITIES	HR COMPLEMENTARITIES	TOP-LEVEL MGMT COMMITMENT COMPLEMENTARITIES
Independence Model Chi square (χ^2) (df)	320.96 (55)	381.44 (45)	267.96 (28)
Satorra Bentler Scaled Chi Square (χ^2) (df)	48.80 (33)	63.21(31)	23.89 (12)
Bentler-Bonett Non-Normed Fit Index CFI	0.95 0.97	0.84 0.89	0.94 0.98
BOLLEN (IFI) FIT INDEX	0.97	0.90	0.98
RMSEA	0.068	0.147	0.079
90% CI for RMSEA	(0.000, 0.125)	(.099, .193)	(.000, 0.167)
Model AIC	-24.65	6.61	-7.87
Independence AIC	210.96	291.44	211.96

Table 5: Structural Effects

Model 1: Higher Order complementarities in use of Flexible Mfg. IT Systems

HYPOTHESIS	STRUCTURAL COEFFICIENT (β)	STANDARD ERROR	t- STATSTIC
Higher Order Complementarities	0.65	0.10 (0.10)	1.98* (2.15*)
Top-Level Mgmt. Commitment – Agility	0.38	0.07 (0.07)	2.54* (2.35*)
Flexible Mfg. IT systems - Agility	-0.07	0.18 (0.18)	-0.50 (-0.51)
HR Initiatives- Agility	-0.49	0.45 (0.43)	-1.41 (-1.48)

Model 2: HR IT (Lower Order) complementarities

HYPOTHESIS	STRUCTURAL COEFFICIENT (β)	STANDARD ERROR	t- STATSTIC
HR IT Complementarities - Agility	0.44	0.05 (0.05)	2.41* (2.33*)
HR Initiatives - Agility	-0.20	0.17 (0.17)	-1.57 (-1.59)
Flexible Mfg Sys - Agility	-0.03	0.06 (0.05)	-0.27 (-0.31)

Model 3: Top-Level Mgmt. Commitment and IT(Lower Order) complementarities

HYPOTHESIS	STRUCTURAL COEFFICIENT (β)	STANDARD ERROR	t- STATSTIC
Top-Level Mgt Commitment and IT complementarities - Agility	0.33	0.06 (0.05)	1.865 (2.102*)
Top-Level Mgt Commitment - Agility	0.34	0.07 (0.08)	2.07* (1.91)
Flexible Mfg IT systems - Agility	-0.02	0.07 (0.06)	-0.32 (-0.39)

Note: 1. * p value < 0.05

2. Robust values for standard error and test statistics are reported in parenthesis below the normal values

Note: References and item measures are available from authors upon request.

Corresponding author Pankaj Setia (setia@bus.msu.edu)

We are further working on the comparison of the lower order and higher order effects!