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Taxonomy of ERP Integrations and Plant Performance

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Abstract: The complex nature of today's business poses challenges for supply chain management which embraces dispersed supplier, production and distribution activities worldwide. Enterprise Resource Planning (ERP) has risen to prominence as a result of its promise to integrate business processes from upstream to downstream. The past two decades, however have witnessed complications surrounding ERP implementation; its impact on firm performance has been reported as being inconclusive. This study argues that the extent of ERP integration is a missing link in the story and aims to investigate the hypothesis that the extent of ERP integration is positively associated with plant performance. Using a global sample of 641 manufacturers this research identifies four distinct ERP integration patterns, epitomized by different extents and directions of integration and finds a significant association between the broadest degree of ERP integration and plant performance improvement.

Key words: Business poses, worldwide, story and aims, hypothesis, ERP integration

INTRODUCTION

ERP implementation is important because it enhances a firm's competitive advantage by lowering production costs increasing operational flexibility, strengthening supplier and customer relationships and creating new products and services (Karim *et al*., 2007; Scott and Vessey, 2002). The key benefit of Enterprise Resources Planning Systems (ERPS) is to provide a platform that shares and integrates information across departments and supply chains (Park and Kusiak, 2005; Tarn *et al*., 2002; Bose *et al*., 2008; Al-Mashari *et al*., 2003; Davenport, 1998; Su and Yang, 2010). A company frequently carries multiple sets of unconnected data in various departments, plants or offices and this leads to vast direct and indirect costs in reformatting data for compatibility and decision-making. The seamless integration of information through ERPS enables a firm to consolidate complex and unstandardized interfaces between disparate modules into cross-functional automation. Such a platform allows firms to collaborate on a real-time basis to operate flexibly and quickly absorb demand variability, to foster the decision-making process and to improve throughput, time to market and delivery speeds. ERPS implementation is also beneficial for cost-cutting in unit labor inventory, customer services, operations and panoptic controls. It is evident that the ERPS market has experienced drastic growth over the past two decades. The sales of the largest vendor, SAP have increased 3,300% from <$500 million in 1992 to $17 billion in 2008. The ERPS market around the world expanded drastically to <$33 billion in 2008 and is estimated to exceed $50 billion by 2012. Taking the training, customization and update costs into consideration, the figure will double.

Some firms have experienced phenomenal success with ERPS implementation. For instance, a global mobile phone manufacturer, LG, manages 83 subsidiaries with 82,000 employees in 39 countries using an ERPS suite that synchronizes 440 critical business processes and reduces its IT budget by 20%. ERPS integration enables LG to acquire concurrent visibility in both the upstream and the downstream areas of global supply chains, to shorten the new product life cycle, to facilitate financial and accounting reporting and to reduce ERPS maintenance costs by 50% (Evans, 2009).

Frustration and failures are also reported with regard to ERPS integration. A survey by the consulting firm Robbis-Gioia in 2001 reported that 51% of 232 American firms regarded ERPS implementation as an unsuccessful initiative. A recent survey by Forrester Research reports that >2,200 IT executives in North America and Europe face the burden of updating the key ERPS legacy applications. In an international context, it is reported that only 10% of firms have succeeded in ERPS implementation in China (Zhang *et al*., 2003). ERPS installation costs a firm $17 million for SAP and $12.6 million for Oracle on average and even so there is a 93% chance of time-consuming installation and a 50% chance of confusion in using the system. The need for ongoing customization, the resistance to the use of ERPS among managers and employees, the reorientation

Table 1: Summary of studies on the impact of ERPS on firm performance

Study (relationship)	Sample	ERPs variable	Performance variable	Main analysis	Major findings
Poston and Grabski, 2001 (mixed)	50 US firms (SIC 10-74)	Announcements about ERP adoption 1989-1997	SG&A (selling, general and administrative expenses) COGS (cost of goods sold) Residual income	Paired t-tests	No significant change in financial performance until 3 years after the Implementation residual income of the ERPS and then a significant decrease in costs only for the cost of goods sold as a percentage of sales and in the number of employees as a percentage of revenue, all 3 years after ERP implementation
Hayes *et al.* (2001) (mixed) inventory turnover	91 US firms (several sectors)	Initial ERP adoption announcements	Stock market returns	Event study	Event study although overall the sample reacted positively to the announcements, small and unhealthy firms experienced a negative return from the announcement
Hitt *et al.* (2002) (positive)	4,069 (firms secondary data)	ERP adoption	Sales per employee profit margins, ROS Inventory turnovrer asset utilization accounts receivable turnover, Tobin's q	Regression	ERP implementation slows down business performance and productivit temporarily but Tobin's q increases
Hunton *et al.* (2003) (negative)	63 US firms (SIC 13-80)	Pre- and post-ERP adoption comparison	ROA, ROI, ROS ATO (Asset Turnover)	Regression	Nopre-topost-adoption improvement in financial performance was found for firms that adopted ERP.The financial performance of adopters held steady while that of nonadopters decreased over time during the test period. Large and unhealthy firms experienced negative ROA, ROS, and ROI
Nicolaou *et al.* (2003) (positive)		Pre- and post-ERP adoption comparison	ROA, ROS, ATO		Firms that adopted enterprise systems exhibited significantly higher differential performance in their second year after the complete installation of the system than did the control group
Mabert *et al.* (2003) (mixed)	78 US Firms	Planning, management, customization	Budget, on time implementation	Logistic regression	Despite some improvements in managers' perceptions of performance, few firms had reduced direct operational costs
Matolcsy *et al.* (2005) (positive)	35 firms in Australia and New Zealand that adopted SAP ANZ	Pre- and post-ERP adoption comparison	Net profit margin, Inventory turnover, Fixed asset turnover, Accounts payable days, current ratio and sales change	t-test, MANOVA	ERPS primarily adds value to the operations performance. Some support is found for increased profitability SDO Sales days outstanding, 2 years after the adoption of ERP and for improvements in accounts receivable management
Vemuri and Palvia (2007) (neutral)	17 US chemical and pharmaceut ical firms	ERP adoption	Operational performance inventory level, cash equivalent position, COGS, operating income, SG&A	ANOVA	A majority of the 17 firms failed to improve their operational performance
Wieder *et al.* (2006) (neutral)	89 Australian companies(49 adopters, 40 nonadopters)	ERP adoption ("gonelive")	ROA, ROS, Sales growth rate, cashflow cost reduction programs	Nonparametric tw-independent t sample tests (survey)	Nosignificant performance differences between ERP adopters and the control group were found at the supply chain level or at the overall firm level.However, the further back in time that an ERPS was initially implemented, the higher the overall firm performance
Hendricks *et al.* (2007)	186 US firms	ERP adoption announcements	ROA, ROS, Sales growth rate, cash flow, cost reduction programs	Event study	Stock returns are negative in response to the announcements. There is weak evidence of improvements in profitability during the implementation period
Shen (2008) (mixed)	25 firms in Taiwan	Pre- and post-ERP adoption comparison	10 financial indicators such as receivables turnover inventory turnover, total assets turnover, revenue growth rate,	Paired t test	Most performance indexes show no significant differences after ERP installation. Only inventory turnover and average number days inventory in stock show significant improvement after 2 or 3 years'

Table 1: Continue

Study (relationship)	Sample	ERPs variable	Performance variable	Main analysis	Major findings
			net profit rate, ROE, and ROA		ERP implementation. Other indexes such as ROE and ROEA even show worse performance than before the implementation
Goeke (mixed)	36 US companies with SAP ERP success	Pre- and post-ERP adoption comparison	Differentials for gross margin, operating margin, and net sales	Regression discontinuit y analysis	The gross margin of firms that announced their success with SAP success was significantly greater than that of their matched competitors. However, this was not the case for operating margin

of business processes, the cultural barriers and the substantial costs are the main barriers to reaping the benefits from the implementation of ERPS (Tsai *et al*., 2005; Xue *et al*., 2005; Al-Mashari *et al*., 2003). Despite the reported difficulties, companies perceive ERPS as indispensable software and even as the backbone of the company (Su and Yang, 2010). The question is how much ERPS integration is desired and how useful it is in improving the bottom line of the company. Prior research has delved into this question using event studies, case studies or surveys. Most studies have compared performance of pre- and post-ERPS adoption. This approach could be flawed, because such comparisons do not provide the extent of ERPS integration in a firm or a supply chain. As many studies suggest, ERPS implementation by itself does not necessarily lead to performance improvement but may result in complications in terms of business process changes, training and implementation. What is important is how successfully firms have adopted ERPS and how pervasive the adoption has been in the organization and the supply chain. However, there has been little empirical study of the degree of ERPS integration and the resulting performance differences. This study aims to fill this research gap by classifying ERPS integration patterns and examining their performance divergence. Four distinct ERPS integration configurations were found and the evidence consistently shows the significant association between the broadest degree of ERPS integration and plant performance improvement.

ERPS Integration and Performance

A review of the literature: Some firms have reaped significant operational and strategic rewards from ERPS, while others have failed to realize the expected performance (Karimi *et al*., 2007; Scott and Vessey, 2002). Several research studies have shown a positive relationship between ERPS adoption and financial performance (Hitt *et al*., 2002) but the majority of empirical studies have presented negative or mixed results Table 1). Notably in a study of 186 US firms, Hendricks *et al*. (2007) found negative stock returns in response to ERPS announcements and in a study of 78 US firms, Mabert *et al*. (2003) reported that few firms had reduced their direct operational costs despite certain improvements in managers' perceptions of performance. Quite a few studies found that firms suffered from ERP implementation until after the first and second years but then started reaping the benefits of it (Poston and Grabski, 2001; Hitt *et al*., 2002; Matolcsy *et al*., 2005; Nicolaou *et al*., 2003). Still other studies show a negative (Hendricks *et al*., 2007; Vemuri and Palvia, 2006) or neutral (Hunton *et al*., 2003; Wieder *et al*., 2007; Shen, 2008) impact on firm performance. While these findings are in line with the productivity paradox of information technology (Brynjolfsson, 1993), some researchers point to the ineffective usage of information technology as the reason for such results (Stratopoulos and Dehning, 2000). In response to the mixed results, researchers have tried to explain the role of organizational, technical, user, task or environmental factors that may affect adoption, implementation or outcomes (Karimi *et al*., 2007). Although many studies have examined the mixed results, most of them do not adequately explain such outcomes of implementation. Previous studies have compared performance differences between ERPS adopters and nonadopters (reference needed). However, this comparison may not reflect which firms have successfully put ERPS into operation. An alternative way of observing the issue is to examine the scope of the ERPS integration that a firm takes time to implement. Since, ERPS implementation often involves difficulties in performance measures, this results in complications. As ERPS implementation covers not only production and operation but also other areas such as accounting, human resources and product life cycle integration provides economies of scale and scope to the constituents of the supply chains. For this reason, the present research sets out to explore the configuration of ERPS implementation and its association with firm performance.

ERP integration and firm performance: Despite inconclusive studies surrounding the relationship between ERPS integration and firm performance, there are several reasons why integration may be positively associated with performance.

First, ERPS facilitates knowledge sharing and coordination among individuals, groups and organizations in the supply chain. According to a knowledge-based view of the firm organizations apply principles and transform expertise in the community into valuable products and services (Kogut and Zander, 1992). Such a transformation can effectively take place in an environment where an array of cross-functional expertise is effectively exchanged and integrated to create novel expertise. ERPS is conducive to providing such a platform. It combines data in silos into an integrated data warehouse and makes it available throughout the supply chains. Such integration enables a firm to understand demand oscillation in the front-end and reflect the changes in the upstream on a real-time basis and increase collaboration along the supply chain and as a result to synchronize customer wants with manufacturing, suppliers, distributors and beyond (Lee and Whang, 2004; Rosenzweig *et al*., 2003; Narasimhan and Kim, 2002; Frohlich and Westbrook, 2001) .

Second, ERPS restructures business processes to enhance organizational integration. ERPS implementation goes beyond the technological level. This is because any ERPS embeds certain assumptions about doing business into the system and these may or may not be the best assumptions for the adopters. Thus, an adopter has to either reengineer its business processes to fit into ERPS processes or adapt the ERPS to its business processes. As an executive of a company said, "SAP isn't a software package; it's a way of doing business" (Davenport, 1998). Time-consuming customization takes a firm a great deal of time and incurs considerable cost and this process is often identified as being responsible for implementation failure. Upon successful integration, however, the restructuring allows firms to revamp inefficient practices and improve efficiency throughout the supply chain (Davenport, 1998; Granlund and Malmi, 2002; Hong and Kim, 2002; Zhu *et al*., 2010).

Third, ERPS enables a firm to achieve a swift and even flow of materials and products from suppliers to customers. Manufacturers often face problems with part shortages inventory, quality, delivery and cost increases which are often the results of inept internal and external supply chain integration. According to the theory of swift, even flow, manufacturers can achieve financial gain through a swift and even flow of materials and products in the manufacturing and supply chaining process (Schmenner and Swink, 1998). A swift and even flow helps a manufacturer to eliminate non-value-added activities such as overproduction, waiting, transportation, unnecessary processing steps, stocks, motion and defects. Bottlenecks and wide variability in operations are other factors that hinder a swift and even flow. By enhancing supply chain visibility, collaboration and efficiency of processes, ERPS enables a firm to integrate fragmented, unstandardized and uneven operations and thus decrease the net costs of business (Su and Yang, 2010; Park and Kusiak, 2005; Akkermans *et al*., 2003; Palaniswamy and Frank, 2000; Frohlich and Dixon, 2001). Thus, we hypothesize,

Hypothesis: Companies with the greatest ERPS integration will have the largest rates of performance improvement.

MATERIALS AND METHODS

Sample: Empirical evidence was drawn from the 2005 round of the International Manufacturing Strategy Survey (IMSS IV) to test the hypothesis. A global network of researchers from 23 countries coordinated this research project and a total of 761 responses were gathered with the average response rate exceeding 25%. The respondents are typically vice presidents or directors of operations management. To ensure content validity where English is not the native language of the respondent, the survey was translated into the respondent's language and back into English. For more information about IMSS research, Lindberg *et al*. (2013) and Frohlich and Dixon (2001). A total of 641 responses were included in this report after deleting incomplete data and the profile of the sample is summarized in Table 2.

The instrument: To ensure content validity, the validity of the instrument and the appropriateness of scale construction were checked (Nunnally, 1978). In this study, nine different categories measured the direction and extent of ERPS integration: material management, production planning control, purchasing and supply management, sales management, distribution management, accounting and finance, human resource management, project management and product life-cycle management. These different modules cover important domains of the enterprise system laid out by Davenport (1998). All types of ERPS integration were measured on Likert scales with 1 representing no use and 5 high use.

Cluster analysis: To identify ERPS integration types, a two-step clustering procedure was used (Ketchen and Shook, 1996; Hair *et al*., 2005). First, a hierarchical method

Table 2: Profile of respondents

Regions	n	%	Industry by ISIC	n	%	Size*	n	%
Asia/Pacific	121	18.9	28: Fabricated metal	235	36.7	Small	154	24.0
Europe	332	51.8	29-30: Machinery	148	23.1	Medium	319	49.8
North America	56	8.7	31-32: Electronics	131	20.4	Large	162	25.3
South America	82	12.8	33: Medical/Optical	28	4.4	Missing	6	0.9
Middle East	50	7.8	34-35: Automotive	96	15.0			
			36: Miscellaneous	3	0.4			
Total	641	100.0		641	100.0		641	100.0

Small: n (the number of employees) = 100; Medium: 100<n = 500; Large: n>100

Table 3: Discriminant analysis for ERPS integration

		Predicted group membership			
Group	No. of cases	Laggards	Concentrators	Explorers	Reinventors
Laggards	77	71 (94.1)*	2 (2.6)	4 (5.2)	0 (0)
Concentrators	184	1 (0.5)	175 (94.4)	5 (2.7) 3	3 (16)
Explorers	180	4 (2.2)	0 (0)	174 (96.7)	2 (1.1)
Reinventors	200	4 (2.0)	0 (0)	5 (2.5)	191 (95.5)

Overall percentage of grouped cases correctly classified: 95.3% *Percentage in parentheses

determines the number of clusters and cluster centroids. Ward's partitioning method with squared Euclidean distance was used for its proven ability to maximize within-cluster homogeneity and between-cluster heterogeneity and to recover known cluster structure (Aldenderfer and Blashfield, 1984). The squared Euclidean distance measure is known to minimize the sum of squares error when used with Ward's method (Arabie, 1994). Standardization of the variables may need to be considered when the scales are different among clustering variables. Also, the use of Ward's method is undesirable when outliers are present in the data. However, the scales of the data are consistent and so it was deemed appropriate to use Ward's method. To determine the number of clusters, the dendogram was checked and then the incremental changes in the agglomeration coefficient were examined. These assessments indicate a sizable leap in the agglomeration coefficient in the four-cluster model. To validate the four group model, we tested for heterogeneity across clusters based upon the ERPS modules. All 9 modules differed significantly in a test of mean rank differences across the four clusters ($p<0.000$) which suggested that distinct groups were identified. After determining the number of clusters, K-means cluster analysis was performed to classify 641 companies into four groups. Cluster analysis is not strictly subject to the assumptions of multivariate statistics such as normality, linearity and homoscedasticity, but researchers have to pay attention to multicollinearity (Hair *et al*., 2005). To check multicollinearity, the tolerance value and the Variance Inflation Factor (VIF) are examined. A tolerance of <,0.10 or a VIF of>10 indicates the presence of multicollinearity among the variables (Hair *et al*., 2005; O'Brien, 2007). The tolerance value ranged from .246-564 and the VIF from 1.77-4.10, signifying that multicollinearity is not a serious issue.

To examine the reliability and stability of the proposed four-cluster solution, we conducted three checks. First, the data were randomly divided into halves and the abovementioned two-step cluster analysis was conducted. The four-cluster solutions in each of the two split-halves exhibited a similar pattern and the four-cluster solution shared the most similarities. Our decision to choose the four-cluster solution was also guided by the interpretability of the clusters. The four-cluster model showed a comparably large leap in the agglomeration coefficient, but the four-cluster model was deemed stable and consistent across different samples. In addition, the sample was divided by firm size and the cluster analysis was confirmed. We thought that small firms might display different numbers of clusters but surprisingly the results from the small, medium and large firms consistently yielded four clusters. Second, discriminant analysis was employed to assess the reliability of the cluster solution, with the 9 items for ERPS given as independent variables and group membership as the dependent variable. The analysis confirms that 95.3% of the respondents were categorized properly which is evidence of good differentiation among the four groups as shown in Table 3. Third, we consulted two ERPS implementation professionals who had extensive careers in ERPS. They examined the cluster configurations and confirmed that the taxonomy reflects the current snapshot of ERP implementations.

A taxonomy of ERPS integrations: Table 4 shows the taxonomy of ERPS integrations from the cluster analysis.

Cluster 1: Laggards. We tag cluster 1 as the "laggards" due to the small extent or complete lack among them of adoption of ERPS integration. The mean values of this group are<2 which indicates that firms in this group have not adopted ERPS or use it to a very small degree. In all, 12% of the sample fall into this cluster which shows that a significant number of 11 companies have been using

Table 4: Taxonomy of ERPS integrations

Integration type Items	Mean	SD	Laggards	Concentrators	Explorers	Reinventors
Material management	3.85	1.2	1.84	1.84	3.18	4.65
Production planning and control	3.75	1.21	1.61	1.61	3.37	4.56
Purchasing and supply management	3.85	1.15	1.82	1.82	3.3	4.66
Sales management	3.24	1.26	1.38	1.38	3.04	4.2
Distribution management	3.09	1.33	1.29	1.29	2.69	4.23
Accounting and finance	3.88	1.18	1.95	1.95	3.63	4.57
Human resource management	2.66	1.22	1.35	1.35	2.74	3.82
Project management	2.61	1.26	1.39	1.39	3.04	3.54
Product life-cycle management	2.18	1.18	1.17	1.17	2.28	3.1
Number of cases			77 (12%)	184 (29%)	180 (28%)	200 (31%)

basic modules to a very small degree. It seems that the costs and managerial commitments associated with ERPS implementation make a considerable number of firms hesitant to dive into implementation.

Cluster 2: Concentrators: Companies in the concentrators' group limit the scope of ERPS implementation to the core functions for manufacturing, such as material management, product planning and control, purchasing and supply management and accounting and finance. Other modules related to distribution activities and broader supporting functions are implemented only to a small degree. Companies that seek manufacturing efficiency with limited resources pursue this strategy. In all, 29% of the cases fall into this category.

Cluster 3: Explorers: Explorers are companies that implement all 9 aspects of the ERPS modules, to a moderate degree. This group explores the benefits of ERPS implementation, but full exploitation has not taken place yet. It seems that the firms in this cluster are still exploring the benefits of ERPS implementation and working toward fully expanding the system in a broader span. The explorers are the second largest group with 28% of the cases. This percentage shows the struggles that many firms are facing in the course of ERPS implementation. Though they try to adopt the system, firms encounter difficulties in fully adopting and customizing it. Consequently, they use the system only to a moderate degree and suffer from fragmented integration.

Cluster 4: Reinventors. The reinventors distinguish themselves from other clusters in particular in human resource management, project management and product life-cycle management. Due to the costs and the strenuous efforts required for customization, these modules are often viewed as peripheral and secondary components of ERPS implementation. With the business environment becoming more dynamic, those modules could provide a 12 competitive a dvantage. Product life-cycle management, for example, plays a crucial role for manufacturers that have to consider their recycling and disposition methods from the product design stage due to environmental regulations such as the EU's End-of-Life Vehicle Directive. Since adopting these modules requires significant business process reengineering, this group of companies is daring in its efforts to revamp and reorient its business processes with ERPS. These reinventors broaden the scope of ERPS integrations as far as possible and in so doing they maximize intra-and inter-organizational integration. This achieves the synergy offered by ERPS integration. The reinventors form the second largest cluster, comprising 31% of the sample.

RESULTS AND DISCUSSION

The goal of this study is to examine the association between the extent of ERPS implementation and plant performance. The use of external variables not used in cluster analysis is also recommended for validating the identified clusters (Ketchen and Shook, 1996; Hair *et al*., 2005). A total of 24 performance indicators measure three aspects of plant performance: market place, productivity and non-productivity performance (Voss and Blackmon, 1998; Frohlich and Dixon, 2001). Initially, Multiple Analysis of Variance (MANOVA) and Multiple Analysis of Covariance (MANCOVA) were employed to test whether or not all clusters will have the same means for all dependent variables. MANCOVA takes the intercorrelations among dependent variables into consideration and is regarded as more rigorous than bivariate tests such as the ANOVA or ANCOVA procedures. Where a MANCOVA result indicated a significant difference between means, ANOVA and ANCOVA were employed to further investigate the difference between groups.

Assumption checks for multivariate analysis (MANOVA and MANCOVA): Before conducting the analysis, the assumptions of multivariate analysis were examined. First, the skew value and kurtosis of each measure evaluated the normality of the dependent variables. The skew value ranged from 0.719-0.051 and the kurtosis

Table 5: ANOVA and ANCOVA results

Performance Indicator[a]	Laggards (1)	Concentrators (2)	Explorers (3)	Reinventors (4)	ANOVA p-value	ANCOVA p-value	Covariates p-value: Market dynamics	Covariates p-value: Firm size
Marketplace								
Sale[b]	2.74	2.91	2.86	3.05	0.18	0.315	0.00	0.64
Market share	2.49	2.50	2.58	2.71	0.11	0.26	0.00	0.84
Return on sales	2.38	2.52	2.38	2.62	0.17	0.08	0.00	0.01
Return on investment	2.30	2.53	2.37	2.64	0.06	0.04	0.00	0.04
Productivity								
Unit manufacturing cost[b]	2.68	2.73	2.68(4)	2.92(3)	0.02	0.06	0.00	0.36
Procurement costs	2.43(4)	2.62	2.54(4)	2.83(1,3)	0.00	0.01	0.01	0.08
Overhead costs	2.37(4)	2.41(4)	2.54	2.76(1,2)	0.00	0.00	0.011	0.626
Manufacturing conformance	2.96	2.94	2.93	3.08	0.27	0.42	0.00	0.28
Product quality and reliability[b]	3.15	2.99	3.00	3.22	0.02	0.02	0.00	0.29
Product innovativeness	2.76(4)	2.69(4)	2.90	3.15(1,2)	0.00	0.00	0.00	0.27
Product customization ability	2.84	2.76(4)	2.93	3.04(2)	0.02	0.01	0.00	0.02
Volume flexibility[b]	3.03	3.13	2.97(4)	3.27(3)	0.01	0.01	0.00	0.61
Mix flexibilityb	2.92	2.96	2.94	3.11	0.18	0.41	0.00	0.19
Time to market[b]	2.700	2.77(4)	2.890	3.01(2)	0.022	0.104	0.000	0.24
Manufacturing lead time[b]	2.63(4)	2.84	2.79(4)	3.02(1,3)	0.00	0.00	0.00	0.11
Procurement lead time	2.49(4)	2.54(4)	2.58	2.81(1,2)	0.00	0.00	0.00	0.64
Delivery speed	2.75(4)	2.90(4)	2.99(4)	3.26(1,2,3)	0.00	0.00	0.00	0.15
Delivery dependability	3.02	2.98(4)	2.86(4)	3.26(2,3)	0.00	0.00	0.00	0.99
Labor productivity	2.74(4)	2.93	2.86	3.09(1)	0.01	0.01	0.00	0.80
Inventory Turnover	2.69(4)	2.72(4)	2.81(4)	3.12(1,2,3)	0.00	0.00	0.00	0.48
Capacity utilization	2.69(4)	2.72(4)	2.81(4)	3.12(1,2,3)	0.00	0.00	0.00	0.48
Non-productivity								
Customer service and support	2.88	2.83(4)	2.99	3.14(2)	0.00	0.01	0.00	0.73
Employee satisfaction	2.51(4)	2.42(4)	2.63	2.83(1,2)	0.00	0.01	0.00	0.62
Environmental performance	2.57(4)	2.59(4)	2.74(4)	3.09(1,2,3)	0.00	0.00	0.01	0.02

[a]Cluster means for each performance measure (1-deteriorated >10%, 2-stayed about the same, 3-mproved 10-20% , 4-improved 30-50%, and 5-improved more than 50%) are shown in the column. Numbers in parenthesis indicate the group whose mean value is statistically different (Scheffé or Game-Howell pairwise tests with significance level of 0.05) For these measures, a Games-Howell test was used for post-hoc analysis instead of a Scheffé test

from-0.503-0.618 indicating that the variables meet the normality assumption. Second, Box's M score verified the assumption of homoscedasticity. Because Box's M is extremely sensitive to sample size, some researchers recommend setting the significant level at .001, especially when the sample sizes for groups are unequal (Tabachnick and Fidell, 1996). The significance level of Box's M tests was 0.13 and it was deemed as upholding the homogeneity of variance covariance assumption given the large sample size. Third, Leven's test verified the homogeneity of error variances of each group. The results indicated that 7 out of 24 dependent measures have unequal variances among the groups. For those measures, a Games-Howell test was chosen for a post-hoc analysis test. Fourth, the adequacy of the covariates was examined. A covariate should exhibit significant correlation with the dependent variables while having insignificant correlation with the independent variables. The linear associations between the four covariates and the twenty-four dependent variables were tested. Competition intensity and geographical focus were dropped for they were not related to dependent variables. Market dynamics and firm size (i.e., the natural logarithm of the number of employees) had significant correlations with the dependent variables: Wilk's lambda, F values of 4.586 and 2.615, respectively. Following multivariate F-tests, univariate F-tests were conducted and the results show that market dynamics is significantly associated ($p<0.05$) with all the dependent variables while the natural logarithm of company size is significantly related ($p<0.10$) to seven dependent variables. The condition for interdependence between the two covariates and the independent variables was deemed to be satisfied (Tabachnick and Fidell, 1996). In addition, the correlation between market dynamics and the natural logarithm of the firm size was 0.122 which is low.

Multivariate analyses (MANOVA and MANCOVA): Wilk's lambda were checked to assess whether there is a difference across the groups. Wilk's lambda for MANOVA was $F(72,1282) = 1.657$ which is significant at the 0.001 level. To find out if the result changes when the

two covariates are included, MANCOVA was run, yielding Wilk's lambda of F(72,1264) = 1.578. It was significant at the 0.002 level. The groups display significant differences in performance regardless of the presence of the two covariates. Such a significant difference provides a good reason for further post-hoc analysis of dependent variables using univariate tests such as ANOVA and ANCOVA.

Univariate analyses (ANOVA and ANCOVA): ANOVA was conducted with the Scheffé tests chosen as the main post-hoc analysis method. The Scheffé tests take group size difference into consideration. Where the homogeneity of groups variance was violated, the Games-Howell method was used for post-hoc analysis. The result shows that 17 out of 24 measures exhibit significant differences between the four ERPS integration patterns (Table 5). In order to see the impact of the two covariates, ANCOVA tests were conducted with market dynamics and firm size as covariates. The result did not show a significant difference except for two dependent variables, time to market and inventory turnover. The significance level increased from .022-104 for time to market and from 0.013-0.053 for inventory turnover. At the 0.01 level, the coefficients are still significant. This result strongly supports the hypothesis that companies with the greatest degree of ERPS integration will have the largest rates of performance improvement. The reinventors which have the broadest and largest degree of ERPS integration, exhibited consistently better performance improvements than the rest of the groups. Interestingly, however, the other three groups were not distinguished from each other in performance outcomes. These results suggest that the scope of ERPS integration matters in realizing performance benefits. While the fullest integration enables firms to reinvent all the business processes and achieve seamless coordination, partial or fragmented integration may take time to realize the promise from ERPS integration.

Available evidence shows that a company's market performance initially suffers for a year or two after the ERPS implementation of ERPS and begins to reap the benefits of implementation after three years. While it is valuable, a comparison of pre- and post-performance may not reflect how well a company has implemented ERPS. Just like any other tools and technologies, ERPS needs careful planning and the allocation of sufficient resources to make the implementation successful. Thus, it might be more useful to examine the scale and scope of ERPS implementation and related performance differences associated with dissimilar patterns of ERPS implementation. The results of our analysis suggest a clear divergence between the fragmented integrators and the reinventors. A closer examination of the results elicits the following observations. First, the extent of ERPS integration matters. The reinventors consistently displayed the largest rate of significan performance improvements. Noticeably, the reinventors took a comprehensive approach to ERP.

In addition to the supplier and distribution aspect, the reinventors paid attention to integrating human resource management, product life-cycle management and project management. This suggests that extending integration over operational scope has become important in improving productivity. According to a knowledge-based resource view, seamless integration facilitates knowledge sharing and proliferation among the constituent parts of technology users. As the integration embraces human resources, products and projects, all-directional integration enables firms to conveniently integrate, revamp and structure their existing processes and reflect customer needs effectively.

Second, manufacturers may consider expanding the scope of ERPS integration to broader area. The majority of companies were implementing ERPS in core modules and distribution and finance. However, only the reinventors made significantly better performance improvements than the other three types. This finding suggests that expanding the scope of ERPS to all parts of the supply chain is advantageous for firms. Due to the cost and customization issue, firms are cautious in enterprise-wide ERPS implementation. While this is understandable, limiting the scope of ERPS to certain areas still leaves room for fragmented implementation flows and makes the supply chaining less effective. Manufacturers may wish to review their ERPS strategy and reassess its effectiveness for increasing productivity and nonproductivity measures. As the implementation modules span the overall supply chain, the time needed for implementation might become considerably prolonged. However, reevaluating a company's ERPS strategy may be beneficial in refining both the operational and the nonoperational aspects of the supply chain.

Third while market performance appeared to stay much the same across the clusters, the reinventors showed significant productivity and nonproductivity performance increases. Sales, ROS and ROI showed no difference among the groups. This result contradicts our expectation that ERPS adopters would perform better than companies with very limited adoption of ERPS. But laggards sometimes show better performance than concentrators and explorers. This result supports the previous research suggesting that there is little

association between market performance and ERPS implementation (Hunton *et al*., 2003; Wieder *et al*., 2006; Shen, 2008). When it comes to productivity and nonproductivity indicators, however, ERPS works powerfully to make differences. It lowered manufacturing and procurement costs significantly while it increased product quality innovativeness, customization ability and time to market considerably. As for nonproductivity measures, ERPS implementation also helped to enhance customer service, employee satisfaction and environmental performance. This finding is consistent with that of Matolcsy *et al*. (2005) that ERPS added value primarily to operations performance, not to financial performance.

Fourth, we looked at market dynamics and firm size. We initially expected that firm size would influence the scale of ERPS implementation. Our study shows that across firm size, ERPS implementation has similar configuration patterns. In terms of performance, firm size is significant for only a few performance measures, such as ROS, ROI, product customization ability and environmental performance. In contrast, market dynamics is a stronger control variable that exhibits significant relationships with all 24 performance measures. The speed of market expansion or decline seems to be closely related to market, productivity and nonproductivity performance.

CONCLUSION

Two main conclusions can b e drawn from this study. First, cluster analysis indicated different patterns of ERPS integration among manufacturers, depending on the reach and depth of implementation: manufacturers can be divided into laggards, concentrators, explorers and reinventors. These groups capture and show the status of the ERPS implementation strategies used by firms in a sizable international database. This classification may assist researchers and practitioners to understand the issues surrounding ERPS integration. To the best knowledge of the authors, no ERPS implementation classification has been presented and validated in other studies.

Second, although our analysis does not establish a causal link between the extent of ERPS integration and performance, it reveals the significant role that the scale and scope of ERPS integration play in improving market, productivity and nonproductivity performance. There has been much debate about the usefulness of extending the use of ERPS over the organizational and supply chain functions. The issue of the relationship between the adoption of technology and its impact on firm performance has been debated as investment in a technology becomes costly and time-consuming. As ERPS becomes an integral part of industry with the promise of transforming business processes, firms generally see pressure from competitors as a reason to adopt and implement ERPS but its business value has been uncertain. This study finds that companies with the largest scale and scope of ERPS integration can be differentiated from other manufacturers. While financial performance did not improve in the short run, operational and non-productivity-related performance improved significantly as the ERPS integration progressively covered major aspects of the supply chains. Startlingly, adopting either core ERPS modules or general modules did not produce any competitive advantage over firms with no or little implementation of ERPS. But the firms that integrated manufacturing and supply chains with human resources, product life-cycle and project management produced distinct performance improvement.

This study also leads to some important implications for theory and managerial practice. From a theoretical perspective this study raises the issue of the extent of ERPS integration. In his seminal study, Davenport (1998) suggested that ERPS implementation faces three important challenges: determining what modules to adopt, how much to customize and how to reconcile legacy systems with ERPS. Previous empirical studies have paid scant attention to the degree of ERPS integration and thus this study has suggested an association between the degree of integration and firm performance. While this study is a good start, the literature suggests that there are at least three areas of integration: the physical, technical and process reengineering integration of ERPS (Parr and Shanks, 2000). This study has focused only on the physical aspect. However, both the business process reengineering area and the technical area are also important aspects of ERPS integration. For example, each ERPS carries its ingrained business processes and each firm that adopts a specific ERPS faces a decision on how to determine the trade-offs between adopting business processes from the ERPS system and adapting it to extant business processes. Such interaction in ERPS integration is of importance in understanding the complex nature of this integration and its impact on firm performance. Conceptual and empirical research will benefit both academicians and practitioners.

IMPLICATIONS

For managers, this study presents two important implications. First, managers may continue to seek to expand the extent of ERPS integration. The reinventors emerged as the best performers while the rest of the

groups showed little difference in performance. The companies that fall into the reinventors' group should stay on their present path in terms of ERPS integration. Companies with lesser degrees of integration should aim at broadening their ERPS implementation in both reach and depth. As firms engage in comprehensive supply chain integration through ERPS, companies with fragmented ERPS integration may lose the opportunity to achieve seamless coordination and collaboration. In terms of future research, it will be interesting to see why there are four patterns of ERPS integration. Is it because of availability of resources, competitive pressures or inefficiency in operations systems? Some studies suggest that organizational, cultural and industrial factors might lead firms to choose a certain type of ERPS adoption (Al-Mashari *et al*., 2003; Gargeya and Brady, 2005; Hong and Kim, 2002; Tsai *et al*., 2005). The way firms are implementing ERPS is important but so are the processes that lead firms to expand the circle of integration. What has made some firms unafraid of changing business processes spanning suppliers, distributors and various departments?

This study also reveals the need to further investigate the link between ERPS integration and plant performance. While this study shows a strong association between the broadest ERPS integration and plant performance, another study using objective performance measures or longitudinal study methods may verify the results.

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