More Bang From The IT Buck - The Singapore Experience

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Abstract

What are the specific IT applications that bring the most business benefit? Organized around Porter's value chain model of the firm, and using data from a sample of Singapore firms, this paper examines the relation between organizational performance and the computerization of specific business activities. We explore if there are complementarities among IT applications and triangulate the results of multiple analyses to arrive at a conclusion. We use sequence analysis techniques developed in biology and computer science to see if there is a preferred sequence in which activities should be computerized. Findings from the study can guide IT planning in organizations.

Keywords

Business Value, IT Implementation

INTRODUCTION

As firms invest more and more on information technology (IT) every year, it becomes important to assess the impact of such investments on business performance. Historically, some business activities (such as accounting) have proved easier to computerize than others (such as new product development). The relative ease of implementation, rather than the potential impact of computerizing various activities, has often guided the selection of activities to which IT is applied. From an operational standpoint, it makes sense for firms to increase their IT competence by picking the "low-hanging fruit" before tackling more ambitious projects. From a strategic perspective, however, it is the high-impact (rather than easy) projects that deserve priority in the allocation of scarce resources.

Research on the business uses of IT contains many studies of specific IT applications (such as SABRE, the American Hospital Supply ordering system, and so on). However, these studies of particular applications do not add up to a general framework that can guide firms in selecting business activities where IT produces most impact. For the most part, firms do not know the relative impacts expected from computerizing different business activities.

In this paper, we try to identify the business activities where the application of IT produces the maximum impact. We also study how the benefits from IT increase progressively as more and more activities are computerized. Finally, we examine how the order in which activities are computerized influences the impact of IT on business.

RESEARCH QUESTIONS

We have three main research questions in this paper :

1. What are the business activities whose computerization produces the most business impact ?
2. Is the impact from computerizing multiple business activities together greater than the sum of the individual impacts ? In other words, are there complementarities between IT investments in different business activities ? Is the whole indeed greater than the sum of its parts?
3. How does the order in which different activities are computerized influence the overall impact of IT?

THEORY

A taxonomy of business activities: the value chain

To develop an exhaustive list of business activities undertaken by firms, we used Porter’s value chain model (Porter, 1985) which identifies five primary activities (inbound logistics, operations, outbound logistics, distribution, and sales / marketing), and five supporting activities (procurement, R&D, human resource management, finance and accounting, and administration). The value chain model is well-known and widely applicable to a broad range of firms (such as those sampled in our study).

Complementarity

Complementarity implies that the returns from undertaking two or more activities simultaneously exceeds the sum of the returns from each activity alone. Complementarities among business practices have been investigated most thoroughly by Milgrom & Roberts (1990; 1991; 1995), who have adopted Topkis’ (1978) notion of supermodular functions to operationalize the concept of complementarity.

The possibility that IT applications in different activities may have complementarities with one another was proposed in Das & Das (1996). To make the abstract economic idea of complementarity more concrete in an IT setting, the following illustrative example may be useful. Consider, as an example, the benefits of source data automation - the automated capture of transaction-level data using bar-code scanners. While automated data capture reduces the labor costs and error levels of manual data entry, this alone may not justify a large investment in source data automation technology. Now consider an IT application such as data mining (detecting managerially significant patterns in large volumes of data), which may get a poor cost-benefit appraisal, if it is applied to traditional accounting data. However, when we apply data mining technology to scanner-captured data, the resulting payoff may justify investments in both IT applications. To extend the example, let us add a third application - a store charge card that enables customers to pay for their purchases without resorting to cash. Use of the store card has to be encouraged through discounts and promotions, and the benefits arising from it - customer loyalty and higher purchases - may or may not justify the store's investment in the card. When bar-code scanning and data mining technologies are available, however, the ability of the store card to associate each item purchased with a specific customer becomes a major benefit. Using bar-code scanners to capture data, the store card to identify customers, and data mining to analyze the sales data, it is possible for the store to model precisely the buying behavior of each (repeat) customer, preparing the ground for targeted “micromarketing” initiatives (Ing & Mitchell, 1994). The three IT applications - bar-code scanning, data mining, and the store charge card - display significant complementarities, in that the payoff from adopting one of the applications increases sharply with the use of the other applications.[1]

Traditionally, IT has been relied upon to provide lower labor costs, faster processing, and reduced error rates in transactions - all resulting from the automation of transaction processing. Zuboff (1988) pointed out that IT can also be used to "informate" processes and generate data that can be used for management and control. The generation of detailed and up-to-date information is thus another component of the overall benefit function for an IT portfolio. Information generated by IT applications may improve the firm's understanding of customer preferences and product performance, enabling smaller inventories and more frequent product improvements. The complementarities between better information, small inventories and frequent product improvements are easy to see. More detailed information on customers and products can be leveraged if products are frequently improved. To make such frequent product improvements viable, inventories need to be kept small. Small inventories can be maintained (within acceptable risks of stockout) only if sound information on customer preferences is available. Investments in IT that enable all three benefits - better information on customers / products (bar-code scanners), small inventories (EDI), and frequent product improvements (CAD / CAM) - thus bring much greater returns than investment in one or two of the three applications.

Since our study examines the use of IT throughout the firm (i.e. in all business activities), it is logical to investigate whether firms that have deployed IT in many activities have reaped “disproportionately” greater rewards than those applying IT on a more limited scale. Of course, for firms to realize complementarities from IT applications across a broad range of activities, the applications need to be integrated (in terms of interoperability of applications, standardization of data formats, and common user interfaces).

Order effects

The systemic nature of IT implies that the applications already in place at a point in time constrain (under the euphemism “legacy”) the deployment of additional applications. These constraints arise from the choice of hardware and software platforms as well as data definitions and programming strategies. Since IT applications differ widely in their hardware, software, data and programming characteristics, decisions made in the context of one application may well turn out to affect (often, but not always, unfavorably) the development of other applications. For example, a centralized mainframe-based environment for the secure processing of financial data may turn out to be an impediment when sales personnel need to be provided flexible dial-up access to data. Conversely, a PC-based network developed in the R&D lab may not stand up to the stability and security requirements of on-line transaction processing. On the positive side, a materials planning system developed for factory operations may facilitate the future development of applications for management accounting or purchasing. Since firms may choose different sequences for the deployment of IT in various business activities, they may be viewed as following different “trajectories” of IT deployment. Our interests in this paper are

- to characterize the more common trajectories of IT deployment in business activities, and

[1] The example can be extended further by showing the linkage of the scanner data to the inventory control application, enabling automatic re-ordering as stocks of particular products run low. Suites of IT applications such as the one described here are becoming commonplace in the retail industry. For example, Wal-Mart, a large US retailer, routinely uses scanner data to track sales, stock its shelves, design promotions and set prices (Business Week, 1994).

- to examine whether some trajectories of IT deployment are associated with greater business impact than others (i.e. whether it is better to do some things before others).

DATA

The data we use were collected in 1992 through a broad survey of firms in Singapore. Each firm in the sample responded to two separate questionnaires. One questionnaire, aimed at CIOs / senior IT managers, elicited data on the deployment of IT in various business activities in the firm[2]. The second questionnaire, addressed to CEOs / general managers, focused on the business performance of the firm and the impact of IT on firm performance, as assessed by senior management. The two-pronged data collection effort[3] overcomes the problems of :

- bias on the part of systems professionals that may lead them to overstate the impact of IT in their organizations[4], and
- lack of awareness on the part of senior management about details of IT deployment in the firm.

In all, 673 usable responses from firms that responded to both questionnaires were analyzed for this study. The breakdown of these 673 firms by industry segment is displayed in Table 1.

Industry	**Proportion of sample (%)**
Manufacturing	24.6
Trade	15.2
Transportation	8.2
Financial services	11.1
Tourism & leisure	5.6
Construction & real estate	12.9
Government	6.3
Others	16.1

Table 1: Composition of sample by industry

The level of IT usage in each of the value chain activities was measured by the mean of four dimensions of IT use:

1. the extent to which transactions in the activity are accomplished through IT
2. the extent to which IT is used to monitor the performance of the activity
3. the extent to which IT is used for decision support in the activity, and
4. the extent to which the IT applications developed for the activity are actually used by employees.

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[2] This included the date of deployment of IT in various functions, the scope of IT applications in each function (transaction processing, monitoring, and decision support), and the extent of usage of these applications.
[3] The response rates for the CEO survey was 28.5% while that for the CIO survey was 53.1%.
[4] Top management is more likely to *understate* the impact of IT (Wilson, 1993).

Each dimension of IT use was scored on a 7-point semantic differential scale anchored at "low" and "high" and centered on "moderate".

Firm performance, as assessed by the CEOs / general managers, was composed of the mean of nine items :

- financial performance
    1. market share
    2. return on investment
    3. profitability
- product / service performance
    4. market / product development
    5. product service quality
    6. customer relationships
- business competitiveness
    7. ability to compete regionally / globally
    8. productivity (output per employee)
    9. quality of decisions

Each item was recorded on a 7-point scale running from "low" through "moderate" to "high".

The impact of IT was also assessed by top management along the same nine dimensions as firm performance, i.e. CEOs / general managers stated how much they thought IT improved the performance of the firm along each dimension. IT Impact was also recorded on a 7-point scale running from "low" through "moderate" to "high". The assessment of IT impact by CEOs in terms of its contribution to organizational effectiveness and competitive standing parallels the methodology employed in recent studies of IT value (see for example, the E.I.U. report of 1999 on the strategic value of IT).

The CIOs / IT managers provided information on when particular activities were computerized. From these data, we determined the sequence of deployment of IT in different activities. The CIOs / IT managers also provided information on ten items describing the state of systems integration in the firm (interoperability of applications, data definition and format standards, common user interfaces, and database integration). The mean of these ten items was used as a measure of "technical integration"[5] for a firm. Technical integration is of interest because of its likely role in enabling complementarity among IT applications.

All variables - the levels of IT use in the five primary and five secondary activities, the two dependent variables (firm performance and IT Impact), and the moderating variable (technical integration) - were measured with multiple items and proved highly reliable (Cronbach's Alpha scores between 0.82 and 0.94).

[5] Our concept of technical integration is similar in spirit to Broadbent et al's (1999) category of "boundary-crossing infrastructure" which, they find, facilitates the execution of organizational change initiatives like BPR.

METHODOLOGY

The relative impacts of computerizing different activities are determined through multiple regression. Three different approaches are employed to test for the existence of complementarities. Finally, sequence effects are tested by clustering firms according to the sequence in which they computerized different activities, and then testing for differences in impact / performance among the clusters.

Relative impacts

To determine the relative impacts experienced from computerizing various activities in Porter's value chain, we perform multiple regression using the levels of IT usage in the ten (primary and supporting) activities as the independent variables. Two separate regression models were fitted, one with IT Impact as the dependent variable and the other with firm performance as the dependent variable. Multicollinearity is reduced by centering the independent variables, and relative impacts are estimated from the standardized regression coefficients.

Tests for complementarity

As Athey and Stern (1996) point out, the empirical testing of complementarities continues to be a thorny issue. At least three different approaches have been observed in the literature, and we perform all three tests in the interests of triangulation.

Correlation

If the levels of IT use in several activities are highly correlated, it may suggest that the applications of IT in these activities are complementary. The reasoning employed here is a sort of post hoc "sensemaking" - economically rational actors would adopt several innovations if their benefits were mutually reinforcing. However, complementarity is not the only possible explanation for the observed correlations among the independent variables (others include economies of scale, and decision making by fiat), though its presence would be sufficient to explain them. Also, this approach does not relate complementarity to observable measures of IT Impact or firm performance.

Index numbers

The issue here is whether the sheer number of activities computerized contributes to IT Impact or firm performance, above and beyond the contributions attributable to the activities themselves. This approach is implemented by multiple regression, where two index numbers are included as additional independent variables (besides the levels of IT in the various activities). One index number denotes the number of primary activities computerized, while the other refers to supporting activities. Two regression equations are estimated, one using IT Impact as the dependent variable, and the other using firm performance.

Interaction terms

A more "direct" approach to testing for complementarities is to incorporate interaction terms into the regression models for IT Impact and firm performance. In this paper, we model the interactions between pairs of adjacent primary activities in the value chain (inbound logistics and operations, operations and distribution, distribution and sales, and sales and service). The rationale for including these interactions is that activities contiguous in the value chain exchange more information with one another, so that computerization of one is likely to benefit the other.

Since we are interested in the relative impacts of computerizing different activities, we continue to focus on standardized regression coefficients. Standardized coefficients need to be computed and interpreted carefully in the presence of interactions. We employ the Friedrich procedure for computing standardized regression coefficients (Aiken & West, 1991). Following this procedure, the coefficients of interest are the "raw" coefficients estimated using standardized values of the independent variables (and building the interaction terms after standardization).

Sequence analysis

Using information on when each firm computerized the different activities, we established the sequence of IT implementation at each firm. The key analytical task in testing for order effects is to measure the "similarity" among different sequences (Abbott, 1986; 1990). Firms with similar sequences are then clustered together, following which we can test for differences among the clusters on selected dependent measures.

Measuring similarity between sequences

Two sequences are similar if one can be easily transformed into the other. Transformation of sequences employs three kinds of operations : insertions, deletions, and substitutions. By setting suitable "costs" for these three operations, the total cost of transforming one sequence into another can be computed. Dynamic programming algorithms developed in the fields of biology and computer science (where sequence techniques are used for gene sequencing and cryptography respectively) find the least-cost transformations between sequences; these costs are used as measures of "distance" (inverse of similarity) between sequences. Since this distance measure is affected by the lengths of the sequences being compared, we restricted sequence analysis to a sub-sample of 57 firms that had already computerized at least nine of the ten value chain activities. This way, all the sequences compared to one another are of similar size (nine or ten units long).

Clustering

The distance matrix among the 57 sequences was processed by a cluster analysis algorithm (hierarchical clustering, between-groups linkage method). The number of clusters was determined visually from the dendrogram.

Analysis of Variance (ANOVA)

Differences in IT Impact and firm performance between the clusters of firms were tested using one-way ANOVA. Duncan's multiple comparison procedure was used to compare the clusters.

FINDINGS

For clarity of exposition, we present below our findings with respect to only one of the two dependent variables - IT Impact. All the analyses were repeated for the other dependent variable, firm performance. We obtained very similar results for the second dependent variable.

Relative impacts

As would be expected, the computerization of the value chain activities has a significant effect on the business impact of IT assessed by the CEOs of the firms (R^2=0.15, $F_{(10,649)}$=11.25, p=0.000). The activities whose computerization produces the maximum business impact are **operations** (β=0.184, t=4.439, p=0.000), **sales** (β=0.149, t=3.016, p=0.003), and **accounting**

(β=0.108, t=2.508, p=0.012). All other regression coefficients are statistically insignificant at the 5% level.

Tests for complementarities

Little evidence was found for the existence of complementarities. The correlation coefficients are significant (but may have other explanations besides complementarity). The number of activities computerized explains no variance in addition to that explained by the individual activities themselves. Finally, of the interaction terms introduced into the regression model, only the (sales X service) interaction term is statistically significant.

Correlation

The correlation coefficients among the levels of IT usage in the primary and supporting activities range from 0.2 to 0.6, indicating moderate positive correlation. This suggests that firms that have computerized some activities do tend to also computerize the others. Such a tendency does not, however, necessarily imply complementarities among the activities, since other factors (such as overall IT competence, size of IT budget, and so on) could also explain the observed correlations.

Index numbers

Taken alone, the two index numbers - the number of primary activities computerized, and the number of supporting activities computerized - make significant positive contributions to IT Impact (t-values of 3.528 and 2.641 respectively). However, when the index numbers are included in the same regression model as the computerization of the individual activities, they cease to explain any unique variance. Both the index numbers fail to achieve statistical significance as predictors of IT Impact.

Interaction terms

Only the (sales X service) interaction term achieves statistical significance (t=2.051, p=0.041) when introduced into the regression of IT Impact on the levels of IT usage in the primary activities. None of the other interaction terms (inbound logistics X operations, operations X distribution, distribution X sales) are statistically significant. These results persist even when regression modeling is restricted to the half of the total sample that has higher levels of technical integration.

Sequence analysis

For each firm, the sequence in which the value chain activities were computerized was determined. The inter-sequence distances were used to cluster the firms into groups, where each cluster is associated with a “typical” sequence of computerization. Analysis of variance was performed to test for differences among the clusters in terms of the dependent variable, IT Impact.

Clustering

Three clusters containing 22, 14 and 21 firms respectively, were identified from the dendrogram. The three clusters correspond to :

- 22 firms that computerized their primary activities first
- 14 firms that computerized their supporting activities first
- 21 firms that computerized some of their primary activities, then the supporting activities, and then completed the remaining primary activities.

ANOVA

The mean IT Impact was highest (5.42 on a 7-point scale) for the 22 firms that computerized all their primary activities first and lowest (4.41) for those (14) that computerized their supporting activities first. The difference in IT Impact is significant (using Duncan's multiple comparison procedure) between these two groups of firms. The third group of 21 firms, those that started with their primary activities but returned to them only after computerizing the supporting activities, experience an intermediate level of IT Impact (4.71), which was not significantly different from either of the other groups. The average age of firms in the three clusters is the same, and age is not significantly correlated with IT impact.

CONCLUSION

Our findings indicate that the computerization of primary activities, such as operations and sales, generates greater business impact. Of the supporting activities, computerization of accounting has benefited firms the most. Firms are advised to apply IT to their primary activities before turning to applications in general administration or human resource management. The widespread use of IT in these supporting activities, especially when primary activities have not been computerized to their fullest extent, may reflect the ease of developing such applications rather than their business value.

Complementarities among IT applications across the different activities, though possible in principle, appear to be hard to realize. Since the firms with higher levels of technical integration did not fare much better than the others, it seems that technical integration is not sufficient to support complementarity. As indicated in Das & Das (1996), complementarity is a potential that may be achieved by innovations in management thinking and practice - it is not a direct consequence of widespread computerization. Evidence of complementarity in other settings (Milgrom & Roberts, 1995) also suggests that management innovation plays a large part in securing the potential benefits of complementarity when the technical conditions are right.

In terms of sequence of computerization, building IT systems for the primary activities first appears to bring better returns. As discussed earlier, existing IT applications constrain future development, hence legacy systems in the supporting activities may limit the potential of systems in primary activities. It may be a better strategy to implement IT that informates the primary activities and utilize this information in the supporting activities and their IT applications.

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