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PRODUCTIVITY AND PERFORMANCE EFFECTS OF IT-ENABLED REENGINEERING: A FIRM-LEVEL ANALYSIS

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Abstract

We investigate whether the reengineering efforts of companies to leverage potential benefits of using Information Technology (IT) in their business processes improve their productivity and overall firm performance. We analyze firm-level data that covers the period between 1984 and 2004 using a panel data model. We employ standard variables for measuring firm productivity and performance, including labour productivity, return on assets, return on equity, inventory turnover, profit margin, asset utilization, and Tobin's q . Our regression estimations show that (i) firms' performances remain unaffected during the implementation period of the reengineering projects, and (ii) on average, returns to reengineering seem to accrue two to three years after the end of implementation period.

Keywords: Business value of IT investment, Firm productivity, Panel regression.

1 INTRODUCTION

Business Process Reengineering (BPR) is the redesign of processes to gain significant improvements in key areas of performance such as service, quality, cost, and speed. In general, BPR projects involve large investments in Information Technology (IT) and emphasize radical changes in a firm's operations. Since benefits of IT in many cases outweigh the negative interactions with existing organizational practices, and investments in IT and BPR do not succeed in isolation, most BPR projects in the 1990s were implemented using IT as a driver of organizational change.

Several organizations reported to have realized benefits from IT-enabled BPR, ranging from financial benefits to customer satisfaction and growth sustenance. The CIGNA Corporation, for example, successfully completed a number of IT-enabled BPR projects and realized savings of \$100 million by improving customer service and quality while reducing operating expenses. Similarly, reengineering of the accounts payable process at the Ford Motor Company increased the speed of payments and improved company relations with long-term suppliers. However, not all BPR projects end successfully; anecdotal evidence suggests that the payoff from reengineering efforts and IT investments is mixed at best (Barua et al. 1996). Based on interviews with 350 executives in 14 industries, an Arthur D. Little study found that 85 percent of the executives were dissatisfied to some extent with their reengineering activities. Reengineering experts argue that such poor outcomes are due to expecting too much too soon, a lack of partnership between IT and business, and undertaking projects without a complete understanding of costs and benefits.

Given the scale of BPR projects, the major organizational changes they entail, and the potential of failure, it is reasonable to expect BPR projects to have a significant and measurable effect on firm performance. In this research, we investigate the productivity and performance effects of IT-enabled BPR projects using a new data set.

2 LITERATURE REVIEW

This research is related to two streams of previous literature: the work on the business value of IT and the more specialized and limited literature on the value of BPR implementation. We briefly survey the studies in each of these areas that are most relevant to this work. For a more comprehensive literature review on these topics, see Ozcelik (2005).

2.1 Business Value of Information Technology

There is an extensive literature examining the business value of IT at the firm level. The roots of the debate on business value of IT investments can be traced back to 1990s when available data from 1980s and 1990s failed to show evidence of improved firm productivity due to investments in IT in the manufacturing sector (Morrison and Berndt 1990). This result, later called the "productivity paradox of IT," was found to be even more pronounced in the service sector which had used over 80 percent of IT products during 1980s (Roach 1991). Researchers attempted to resolve the paradox by pointing out that the inability to show significant returns may be because of (i) measurement errors of outputs and inputs due to rapid price and quality changes in IT equipment, (ii) the time necessary for learning and adjustment, and (iii) mismanagement of IT resources by firms due to insufficient expertise to take advantage of the potential of using IT in traditional business environments (Brynjolfsson 1993).

Since then, several researchers rejected this paradox by presenting empirical evidence showing a positive relationship between IT investments and firm productivity and performance (Brynjolfsson and Hitt 1996, Lichtenberg 1995, Dewan and Min 1997, Bharadwaj et al. 1999, Kudyba and Diwan 2002). Brynjolfsson et al. (1994) and Brynjolfsson and Hitt (2002) also showed that effects of IT on firm

productivity variables are substantially larger when measured over long time periods, since long-term returns represent the combined effects of related investments in organizational change.

However, not all studies could show a clear payoff from IT. For example, Barua et al. (1991) and Barua et al. (1995) both find that even though IT spending improves intermediate variables of organizational performance such as capacity utilization, inventory turnover, or relative price, it does not necessarily lead to improvements in higher-level productivity variables such as Return on Assets (ROA) or market share. Devaraj and Kohli (2003) emphasized the importance of actual usage in driving the impact of IT on firm performance. Consequently, researchers still debate how the relationship between IT spending and firm productivity needs to be measured and analyzed (Brynjolfsson and Hitt 1998, Dewan and Kraemer 1998, Chwelos et al. 2002).

Compared to the general effect of IT on productivity, however, much less is known about how value is actually generated within the firm (Hitt et al. 2002). Kohli and Devaraj (2003) recommend that future studies explicitly report which complementary changes in business practices, such as business process engineering, business-to-business electronic-commerce initiatives, and enterprise resource planning, accompanied the IT investment. Barua and Mukhopadhyay (2000) emphasize that such analyses will isolate and identify the effectiveness of complementary changes that lead to IT payoffs.

2.2 Business Process Reengineering Payoff

The literature on the impact of IT-enabled business process reengineering and workplace reorganization is small but growing. Brynjolfsson and Hitt (2000) argued that a significant component of the value of an IT investment is its ability to enable complementary changes in business processes and work practices of firms, which may eventually lead to productivity increases by reducing costs or improving intangible aspects of existing products, such as timeliness, quality, and variety.

Researchers using data from banking industry found that the impact of IT investment on bank performance was realized after a certain time lag, and the level of impact depended on the extent to which firms supported their IT investments with organizational redesign (Murnane et al. 1999, Hunter et al. 2000). Additionally, Devaraj and Kohli (2000) showed that IT investment contributes to higher revenue after certain time lags, and the effect is more pronounced when combined with BPR initiatives. Bresnahan et al. (2002) studied the effect of three related innovations (information technology, complementary workplace reorganization, and new products and services) on demand for skilled labour, and found firm-level evidence that the demand for skilled labour is complementary with all the three innovations. Bertschek and Kaiser (2004) analyzed a cross-sectional data set to understand the relationship between investment in IT, non-IT investment, labour productivity, and workplace reorganization, and found that workplace reorganization induces an increase in labour productivity that is attributable to complementarities between various input factors, including IT, and workplace reorganization.

The above studies on IT-enabled BPR and workplace reorganization suggest that there are substantial benefits for firms that successfully implement the associated structural changes, although they do not explicitly measure the resulting improvements in firm productivity and performance. In this regard, our research contributes to the literature from the following perspectives: *(i)* the productivity and performance effects of IT-enabled reengineering are investigated both during and after the implementation period, *(ii)* in order to capture cross-sectional and time-series differences, panel data regression model is implemented, *(iii)* the scope of BPR projects are explicitly considered in the model, and *(iv)* a newer data set covering the period between 1984 and 2004 is used.

3 HYPOTHESES

We expect firms engaging in IT-enabled BPR to experience a difference in their performance. Due to high costs of these projects, it is possible for firms to see a decrease in performance during the

implementation period. The monetary costs of a BPR project may include purchasing new equipments, hiring talented personnel who are capable of using these equipments, training existing employees to handle new roles, or payments to consulting firms if an outside expert advice is needed. Projects may also entail non-pecuniary costs. Due to its nature, BPR modifies and may even obliterate existing business practices of a firm; such organizational changes may lead to an initial turmoil and adversely affect firm performance during the implementation phase of the project. This suggests the following hypothesis:

HYPOTHESIS 1. Firms experience a drop in performance during BPR implementation.

Once a BPR project is finalized and implementation risks are successfully resolved, employees are likely to become more comfortable with the new process design over time, and hence firms will be able to operate efficiently. Examining possible lagged effects of IT-enabled BPR on firm performance variables is especially important because it may take several years for IT investments to translate into performance effects, partially due to the time required to learn and effectively use new systems (Kohli and Devaraj 2003). Not using lagged variables in empirical studies has been cited as one of the factors contributing to the productivity paradox of IT (Brynjolfsson and Hitt 1996, Dewan and Min 1997). After a sufficiently long interval, we expect firms' performances to revert back to their pre-BPR levels, or even surpass them. We therefore hypothesize:

HYPOTHESIS 2. Firm performance improves after the completion of BPR projects.

BPR projects vary considerably in size; some projects focus on a few business functions, such as order fulfilment and accounts payable, while others are implemented at the enterprise level. The scope of these projects may affect the level of impact on firm performance. Our third hypothesis is thus:

HYPOTHESIS 3. The effect of BPR projects on firm performance increases with project scope.

4 DATA

Our research covers the projects conducted between January 1, 1985 and December 31, 2000. We obtained the press announcements for these projects from two leading news sources: ABI/INFORM and Lexis/Nexis. Based on a careful examination of several candidate announcements, these databases were queried by using combinations of key words, including "reengineering", "BPR", "redesign", "reorganization", and "information technology." Every news article mentioning a specific BPR project was considered. However, given our intent for measuring performance effects over the years, we mainly focused on the news articles that provided a time frame for these projects. We observed that most of the projects announced were undertaken by large U.S. firms. Therefore, we decided to focus on firms that were listed in Fortune 1000 in 1998. Overall, 116 of these Fortune 1000 firms were found to have implemented one or more BPR projects between 1985 and 2000. Among the reengineered business units were finance, purchasing, accounts payable, customer service, supply chain, inventory planning, and distribution. We utilized the Standard and Poor's COMPUSTAT database to extract our regression variables. Overall, our data includes a total of 19887 firm-years of observations that span the period between 1984 and 2004.

4.1 Dependent and Independent Variables

We constructed various measures to calculate labour productivity, financial firm performance, and stock market valuation (all serve as dependent variables) using standard approaches. One of our key independent variables is the dummy that indicates whether a firm implemented a BPR project during year t ; we call this variable Implementation Dummy. We also used dummy variables (called Post-BPR dummies) that designate the year after implementation (up to five years). For example, if a firm completed its BPR project in 1997, its Post-BPR dummy with a 1-year lag would take a value of one for the year 1998 and zero for all other years, its Post-BPR dummy with a 2-year lag would take a

value of one for the year 1999 and zero elsewhere, and so on. The Implementation Dummy and Post-BPR dummies are abbreviated as “BPR variables” in the model described in the next section. If the regression coefficients for these variables are found to be significant, then we can conclude that engaging in IT-enabled BPR correlates with firm performance.

4.2 Industry-Level Controls

The literature on industrial organization economics supports the view that the structure of the industry impacts the performance of firms. One such industry-specific characteristic is industry concentration. Highly concentrated markets mean fewer competitors, greater ease of collusion, and higher profit margins on goods sold. Industry concentration in our research is proxied by the four-firm concentration ratio. Additionally, we control for industry at the “1½ digit” SIC level to eliminate variation in firm performance due to other idiosyncratic characteristics of different industries.

4.3 Firm-Level Controls

Our firm-level controls include firm size, advertising expenditure, and research and development (R&D) expenditure. As standard in the literature, we used the natural logarithm of the number of employees as a proxy for firm size. There is ample evidence in the economics, marketing, and strategy literature that supports a positive relationship between advertising and firm performance, as well as between R&D expenditures and firm performance. We thus include these two control variables in our model and expect positive relationships with firm performance.

5 EMPIRICAL METHODS

Based on previous work on the business value of IT, we estimate regressions of various measures of firm performance: labour productivity, financial performance ratios, and stock market valuation as measured by Tobin’s q (Brynjolfsson and Hitt 1996, Bharadwaj et al. 1999, Hitt et al. 2002). The derivations of these measures are outlined in Table 1. Similar to Hitt et al. (2002), we use the logarithm of the numerator of each performance measure as a dependent variable, and the logarithm of its denominator as a control variable on the right-hand side. This specification provides flexibility in the relationship between numerator and denominator while still retaining the interpretation as a performance measure. The general form of our model is thus:

$$\begin{aligned} \log(\text{performance measure numerator})_{it} = & \text{intercept}_i + \log(\text{performance measure denominator})_{it} \\ & + \text{BPR variables}_{it} + \text{firm controls}_{it} + \text{industry controls}_{it} \\ & + \text{year dummies}_t + \varepsilon_{it} \end{aligned}$$

We test Hypotheses 1 and 2 using the fixed-effects panel data model as it handles endogeneity issues under certain econometric assumptions. We are currently working on incorporating the scope of each BPR project (enterprise-wide versus functional) in our data sample in order to test Hypothesis 3. Incorporating a scope variable into our model will enable us to provide a necessary linkage between the IT-enabled BPR projects that are at the business unit level with our productivity and performance variables that are at the organizational level. By the time of the ECIS 2007 conference, we will have the results for the tests of this hypothesis as well.

6 RESULTS

The estimation results of the panel data regressions are presented in Table 2. Firm-level controls (size, advertising, and R&D) are significant in the expected direction in many of our estimations. However, Hypothesis 1 is not supported since coefficients for the Implementation Dummy is not significant

except when estimating asset utilization. This implies that firms' performances were not negatively affected during the implementation periods, at least for the firms in our sample.

On the other hand, we find support for Hypothesis 2 since 2-year and 3-year Post-BPR dummies are significant when estimating return on assets, return on equity, and profit margin. That is, returns to BPR seem to accrue two to three years after the end of implementation period. Similar to the results of previous studies on the business value of IT, our results imply that investment in IT-enabled BPR projects should be considered as a long-term decision by firms because of its lagged performance effects. It should be noted that the significantly positive effect of the IT-enabled BPR projects on productivity and performance variables disappears in the 4th and 5th years after the implementation period. This result confirms the fact that the competitive advantage provided by the IT-enabled BPR projects is indeed temporary, as is the case in any other type of investments in IT (Carr 2004).

7 DISCUSSION

We are still analyzing our extensive data set. We are planning to include in our analyses industry capital intensity and industry mean Tobin's q to control for idiosyncratic industry characteristics not adequately captured by the industry controls we already have. We will also consider including market share as an additional firm control variable and, based on the results of previous research, we will expect it to be positively correlated with firm performance. Therefore, the preliminary results reported in this proposal may slightly change, including the significance levels of the variables and R^2 , after incorporating all these factors into the model.

There are certain limitations to this study. One such limitation is that we do not observe the actual dollar amounts spent for BPR projects; we instead use dummy variables to denote years during which firms engage in IT-enabled BPR projects. Our specification assumes that firms incur the same yearly project costs during their implementation periods. It is possible to relax this assumption by interacting Implementation Dummy with firm-level controls. The same method can be applied to Post-BPR dummies as well. Finally, our observations are limited to the projects that have been publicly announced by firms.

In addition to addressing these caveats, future research can concentrate on measuring the change in productivity and performance due to IT-enabled BPR projects at business unit levels, rather than organizational level. This would be possible by defining new productivity and performance measures for different business units and comparing the resulting differences across the business units.

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| Performance Measure | Nominator | Denominator |
|----------------------------|--------------------|---------------------|
| Labour Productivity | Sales | Number of Employees |
| Return on Assets (ROA) | Pretax income | Assets |
| Inventory Turnover | Cost of goods sold | Inventory |
| Return on Equity (ROE) | Pretax income | Equity |
| Profit Margin | Pretax income | Sales |
| Asset Utilization | Sales | Assets |
| Tobin's q | Market value | Assets |

Table 1. Data Construction of Productivity and Performance Measures

| Dependent Variable | Log (sales) | Log (pretax income) | Log (cost of goods sold) | Log (pretax income) | Log (pretax income) | Log (sales) | Log (market value) |
|-----------------------------|-----------------------|---------------------|--------------------------|----------------------|----------------------|-----------------------|-----------------------|
| Interpretation | Labour Productivity | Return on Assets | Inventory Turnover | Return on Equity | Profit Margin | Asset Utilization | Tobin's <i>q</i> |
| Log (assets) | | 0.9725 (1.01) | | | | 0.6306 *** (43.30) | 0.8274 *** (14.12) |
| Log (inventory) | | | 0.0142 *** (3.82) | | | | |
| Log (equity) | | | | 0.3134 *** (8.44) | | | |
| Log (sales) | | | | | 5.3271 *** (4.96) | | |
| Log (employees) | 0.6703 *** (47.96) | 0.9032 (0.97) | 0.6698 *** (41.95) | 1.2102 (1.87) | -2.0104 * (-2.07) | 0.2442 *** (17.48) | 0.0719 (1.32) |
| Industry Concentration | 0.0905 (0.30) | 26.3494 (1.85) | 0.4135 (1.23) | 23.5838 (1.69) | 25.7563 (1.82) | 0.1625 (0.76) | 4.1035 *** (4.85) |
| Advertising | 0.0004 *** (7.40) | 0.0000 (0.02) | 0.0002 *** (4.51) | 0.0001 (0.03) | -0.0015 (-0.67) | 0.0001 *** (4.22) | 0.0002 (1.37) |
| R&D | -0.0001 (-1.01) | 0.0059 * (1.96) | -0.0000 (-0.14) | 0.0057 * (1.96) | 0.0059 * (2.01) | 0.0001 *** (2.61) | 0.0002 (1.06) |
| Implementation Dummy | -0.0487 (-1.06) | 3.5963 (1.66) | -0.0544 (-1.08) | 3.4944 (1.65) | 3.6612 (1.71) | 0.0774 * (2.37) | -0.1131 (-0.90) |
| Post-BPR Dummy (1-year lag) | -0.0459 (-0.77) | 3.1875 (1.13) | -0.0303 (-0.46) | 3.1867 (1.15) | 3.2217 (1.15) | 0.0905 * (2.13) | 0.0606 (0.37) |
| Post-BPR Dummy (2-year lag) | -0.0280 (-0.47) | 5.9628 * (2.12) | -0.0202 (-0.31) | 5.9025 * (2.14) | 5.9672 * (2.14) | 0.0659 (1.56) | 0.0859 (0.52) |
| Post-BPR Dummy (3-year lag) | -0.0435 (-0.71) | 6.5137 * (2.27) | -0.0537 (-0.80) | 6.3607 * (2.26) | 6.6309 * (2.33) | 0.0306 (0.71) | 0.1700 (1.01) |
| Post-BPR Dummy (4-year lag) | -0.0058 (-0.10) | 2.9780 (1.11) | 0.0369 (0.59) | 2.7954 (1.06) | 2.9607 (1.11) | 0.0255 (0.63) | 0.1938 (1.23) |
| Post-BPR Dummy (5-year lag) | 0.0586 (1.05) | 3.1210 (1.19) | 0.0754 (1.23) | 2.8295 (1.10) | 2.8165 (1.08) | 0.0537 (1.36) | 0.3308 * (2.16) |
| R ² | 0.729 | 0.054 | 0.696 | 0.267 | 0.071 | 0.890 | 0.297 |

Values in parentheses are corresponding *t*-values.

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$

Table 2. Regression Results of Firm Productivity and Performance