Productivity and Performance Effects of Business Process Reengineering: A Firm-Level Analysis

Revised - September 2010

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Key Words: Business process reengineering, business value of information technology, productivity, panel regression.
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Abstract

In this paper, we empirically investigate whether business process reengineering (BPR) is associated with enhanced firm productivity and overall performance. We analyze firm-level panel data that covers the period between 1987 and 2008 using fixed effects and first differencing, which are standard methods to account for unobservable firm-level effects. We employ standard variables for measuring firm productivity and performance. We find that one of our key performance variables, return on assets, drops significantly during the project initiation year. According to fixed effects results, the performance and productivity measures improve (in a decreasing manner) after project initiation. We also find that enterprise-wide BPR projects are associated with more negative returns during project initiation. However, there is no clear evidence about their superiority over functionally-focused BPR projects in terms of performance improvements after project initiation. This may be because grand projects are risky and sometimes lead to grand failures.

1. Introduction

Business process reengineering (BPR) is the redesign of processes, typically using information technology (IT), in order to gain significant improvements in key areas of performance such as service, quality, cost, and speed. BPR initiatives usually aim to integrate separate functional tasks into complete cross-functional processes.

During the early 1990s, BPR was consistently ranked as the most important issue for chief information officers (CIOs) because of the opportunities it was believed to create for businesses [13]. Perceptions toward BPR started to change thereafter, as more executives expressed skepticism about the success of their BPR initiatives and as researchers reported disappointing results on those initiatives, especially during mid-1990s. For example, Caron et al. [24] and Murphy [95] reported failure rates of 50% and 70%, respectively. Holland and
Kumar [73] claimed that 60% to 80% of BPR efforts were unsuccessful, while Hammer [61] and Champy [25] argued that 70% of companies obtained no benefit from BPR. More recently, Devaraj and Kohli [46] outlined a number of unsuccessful BPR projects.

Although BPR by itself is no longer hotly debated among information systems scholars, process changes and reengineering continue to enjoy significant popularity and relevance in practice, as it impacts organizational restructuring efforts, quality improvement programs, enterprise resource planning (ERP) software implementations, and the redesign of business processes for e-commerce [3, 34, 109, 111]. In fact, according to a 2008 CIO Insight survey of the IT executives, 36% of the firms consider BPR as the most widely employed management tool.¹ Another 2008 CIO Insight survey revealed that IT executives view improving business processes as their number one priority.² In addition, a survey by the Ziff Davis company concluded that business process improvement was the single most important project type for IT executives in 2007 [69].

So, why the renewed interest? There seem to be a number of contributing factors. Managers may be rediscovering BPR as they seek new ways to solidify their business processes for competitive advantage. Today, more than ever, firms face a rapidly changing business environment and high consumer expectations. In such an environment, the design and implementation of sound business processes are extremely important in achieving the required business performance and flexibility. The need for establishing inter-organizational links through e-business and supply chains have made BPR an even more strategic tool for firms [2]. In addition, reengineering is necessary to facilitate processes across the organizational boundaries and to integrate back- and front-office operations [53, 84].

² See http://www.cioinsight.com/c/a/Research/CIOs-Rank-Their-Top-Priorities-for-2008/
Since BPR projects typically involve substantial investments, justification of their expected returns is necessary to acquire funding. In 2002, for example, the research company Prosci published a report titled “Best Practices in Business Process Engineering and Process Design” based on a survey of 327 organizations from 53 countries. According to this report, 73% of the respondents indicated that they met or exceeded their objectives with their BPR projects – a clear sign of success for BPR. However, the same study also reported that 75% of the time a business case with a projected return on investment had to be submitted for each BPR initiative to secure funding. Given the negative publicity that still surrounds BPR, practitioners would clearly benefit from empirical research that investigates the relationship between BPR implementations and firm performance, since the results of such research could provide guidance in estimating and documenting the potential impact of projects. When outlining future research directions on BPR in 2000, Devaraj and Kohli [45] commented:

“…the literature in BPR implementation is rife with anecdotal evidence and short on rigorous empirical evidence of performance impacts of BPR. There is a definite need to better measure BPR implementations through objective measures, and to relate BPR to organizational performance in the context of other variables that also affect performance.”

This paper aims to fill this gap. We systematically study the productivity and performance effects of BPR using a rich data set compiled from primary and secondary sources. Following Kohli and Devaraj’s [81] call to gather larger samples to assess the lagged effects of IT on productivity, we take a long-term view with a data set that spans 22 years (1987-2008) for large U.S. firms and investigate the relationship between firm performance and BPR implementations. We find that one of our key performance variables, return on assets, drops significantly during the project initiation year. After project initiation, however,

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various performance and productivity measures improve in a decreasing manner. We also find that enterprise-wide BPR projects are associated with more negative returns during project initiation. There is no clear evidence about their superiority over functionally focused BPR projects in terms of performance improvements after project initiation.

The remainder of the paper is organized as follows. In Section 2, we briefly discuss BPR and explain its past and contemporary definitions. We then discuss relevant literature in Section 3, and present our hypotheses in Section 4. We describe our data in Section 5 and empirical methods in Section 6. Finally, we provide the regression results in Section 7, and discuss our contributions, limitations, and directions for future research in Section 8.

2. A Brief History of Business Process Reengineering

BPR as a management paradigm first emerged in the early 1990s with the works of Davenport and Short [38], Hammer [60, 61], Harrington [66], Hammer and Champy [65], Davenport [34], Johansson et al. [77], Klein [80], Dixon et al. [47], Manganelli and Klein [86], and Ovans [101]. According to the 1993 definition by Hammer and Champy [65], BPR is “the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical, contemporary measures of performance, such as cost, quality, service, and speed” (p. 32).

Many early BPR implementations have reported real benefits, ranging from immediate financial benefits to overall customer satisfaction and growth sustenance. For example, the CIGNA Corporation successfully completed a number of BPR projects in the early 1990s [88] and realized savings of $100 million by improving its customer service and quality while reducing operating expenses [24]. Similarly, reengineering the accounts payable process at the Ford Motor Company increased the speed of payments and improved company relations with long-term suppliers [65]. On the other hand, many projects simply failed to
deliver tangible results. Reengineering experts argued that such poor outcomes could be due to expecting too much too soon [65], a lack of partnership between IT and business [88], undertaking projects without a complete understanding of costs and benefits, and not exactly knowing how to redesign a set of related activities [7]. Another explanation for the failure is that seriously troubled companies often consider BPR to be the solution for all their woes [54]. In such cases, however, the problems run far deeper than what can be fixed by reengineering alone.

The poor outcomes during the 1990s may also be attributed to a poor understanding of what BPR was really all about. Even the pioneers of reengineering confessed having made mistakes when defining and promoting BPR. For example, Hammer told the Wall Street Journal in November 1996 that “[he] was insufficiently appreciative of the human dimension” [124, p.A1]. Similarly, Davenport wrote in the Fast Company in 1995 that “The rock that reengineering has foundered on is simple: people. Reengineering treated the people inside companies as if they were just so many bits and bytes, interchangeable parts to be reengineered. But no one wants to ‘be reengineered’” [35, p.70].

Another shortcoming of Hammer and Champy’s approach was that they viewed radical change as “throwing away the old” which received substantial criticism [48] because certain existing processes could be working well and hence did not need to be discarded. In 2001, Hammer [62] asserted that the most important word in the definition of BPR is “process” rather than “radical”. It therefore seems reasonable to suggest that reengineering has evolved in the minds of BPR pioneers [see, for example, 37, 62, 63, and 64], and now represents a continuum of approaches to process transformation. This new view of BPR is also shared by its critics [9, 51, 56, 78, 103, 112, 114, 115]. BPR, as understood today, focuses on business processes and includes both radical and incremental process changes, which should be customized to the problem and the context [92].
Consequently, more recent literature views BPR as a management tool that can aim for modest yet meaningful process changes. Reflecting the changes in perspectives on BPR, Hauser and Paper [67] proposed in 2007 that Hammer and Champy’s definition be modified by replacing “radical” with “meaningful”, further emphasizing the notion that the appropriateness of process changes for the business context is more important than whether they are drastic or incremental [92]. We adopt this modified definition of BPR for the purpose of this study. Broadening the definition of BPR may be one of the major factors behind the recent revival of BPR initiatives, albeit with different labels such as “business process management”. In fact, both the usage of BPR as reported by Bain’s annual management tool survey and the number of articles published on BPR has increased since 2001, providing evidence that such a revival is indeed the case [123].

3. Literature Review

The IS literature on BPR can be grouped into four streams of research [119]. The largest research stream investigates lessons learned from BPR initiatives and outlines critical success factors [15, 22, 24, 29, 36, 49, 52, 58, 68, 85, 97, 109, 115]. Most of the papers in this category are case studies. Another research stream focuses mainly on interorganizational aspects of BPR [26, 27, 82, 106], while a third stream examines the effectiveness of BPR methodologies, tools, and techniques [33, 42, 43, 72, 79, 98, 99]. The research stream most relevant to this study, however, is the fourth one that investigates organizational impacts of BPR.

Some studies in this fourth category aim to explain the relationship between process changes and IT investments, and thereby provide a rationale as to why BPR, supported by closely aligned IT investments, generate value for the firm. In 1995, Barua et al. [7] proposed the theory of business value complementarity based on the theory of complementarity that
was originally introduced in economics by Edgeworth [50]. The notion of complementarity suggests that the economic benefit of a factor increases with the use of its complementary factors. In the context of reengineering, IT allows for innovative business processes, new skills, and new organizational structures [18]. Hence, Barua et al. [7] and Barua and Whinston [8] argue that IT is complementary with organizational characteristics and processes, and that investments in IT are less likely to succeed if done in isolation.

The theory of business value complementarity was further supported by research that has shown that the impact of IT on firm performance is indeed contingent on the coordinated execution of closely aligned organizational changes. Brynjolfsson and Hitt [17] 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 increases in productivity by reducing costs or improving intangible aspects of existing products, such as timeliness, quality, and variety. Devaraj and Kohli [45] showed in 2000 that IT investments contribute to a higher level of revenue when they are combined with BPR initiatives. Bresnahan et al. [14] examined the effect of three related innovations (IT, workplace reorganization, and new products and services) on demand for skilled labor, and found firm-level evidence that the demand for skilled labor was complementary with all three innovations. Bertschek and Kaiser [11] analyzed a cross-sectional data set to understand the relationship between IT investment, non-IT investment, labor productivity, and workplace reorganization. They found that workplace reorganization induces an increase in labor productivity that is attributable to the complementarities it has with IT. Finally, evidence from the banking industry suggests that the level of impact of IT on bank performance depends on the extent to which firms support their IT investments with BPR [74, 94].

Some other studies on the organizational impact of BPR use mathematical modeling to understand the conditions and contexts that favor various types of reengineering efforts.
Buzacott [20] shows analytically that reengineering principles are most relevant when the task time variability is relatively high, typical of situations where the task involves cognitive capabilities rather than routine manual procedures. Such situations are more likely to be found in services rather than manufacturing. Orman [100] adopts a decision model paradigm to quantify the impact of IT on organizational structures and information-processing tasks and to specify the appropriate reengineering efforts that maximize the benefits from IT. His approach applies primarily to information-processing tasks that involve decision making under uncertainty. Seidmann and Sundararajan [110] develop an economic model to study the interplay between IT, employee empowerment, and task consolidation during process reengineering. They show that, unlike the popular notion in the reengineering literature, centralized decision making and bundled tasks are superior to other process designs in a time-based competitive marketplace.

While studies in this fourth research stream have achieved significant milestones in helping us understand various organizational issues that surround process reengineering, none of them empirically documented the impact of BPR on organizational performance at the firm level. In other words, we have a fairly good understanding of the factors that facilitate BPR and the precursors for BPR success, but we do not know whether BPR projects in general have a noticeable impact on the productivity and performance of firms as measured by standard approaches. We contribute to this stream of BPR research by systematically investigating the productivity and performance effects of IT-driven process changes using a rich data set. In doing this, we have benefited greatly from previous work on the business value of IT, in particular research on the firm-level effects of information technology investments [12, 18, 70] and enterprise resource planning implementations [71], both in specifying and refining our empirical models and methods.
4. Hypotheses

Assuming that firms behave rationally, we expect firms engaging in BPR to improve their performance. Firm performance could be measured in various ways, such as labor productivity, financial performance ratios, and stock market valuation. As discussed in the next section, we investigate the effect of BPR implementations on a number of performance measures.

Because of the relatively high costs of BPR, it is possible for a firm to observe a drop in performance and productivity when initiating a project. The monetary costs of a BPR project include purchasing new equipment, hiring talented new personnel who are capable of using the equipment, training existing employees to handle new roles, and payments to consulting firms if outside expert advice is needed. It has been reported that organizations implementing BPR projects may have to increase their training budgets by 30 to 50 percent [3]. Projects may also entail non-pecuniary costs. Given that a BPR project modifies existing business practices of a firm, such organizational changes may lead to an initial turmoil, and thereby adversely affect firm performance and productivity during the initiation phase of the project [59]. The problems that may adversely affect performance include (i) communications barriers between functional areas [89], (ii) lack of communication between CIOs and CEOs [90] as well as between BPR teams and other personnel [55], (iii) resistance from employees who may potentially be affected by the changes brought about by BPR initiatives [108], (iv) management reluctance to commit resources to BPR projects while expecting quick results [32, 90], and (v) failing to address employee habits during implementation [57]. All of these factors collectively suggest the following hypothesis:

_Hypothesis 1._ Firms experience a drop in performance and productivity in the year they initiate BPR projects.
Once implementation risks are successfully resolved, employees are likely to become more comfortable with the new and improved process design, and hence firms will be able to operate more efficiently. It may take some time for IT investments to translate into performance effects, partially due to the time required to learn and effectively use new systems [81]. Brynjolfsson et al. [19] suggest that the organizational impact of IT investments is most pronounced two to three years after the IT investment is made, but in some cases the benefits can be observed sooner than that. Thus, we expect firm performance and productivity to surpass pre-BPR levels after project initiation, although precisely when this would happen is likely to depend on the type of project. This expectation is also consistent with the anecdotal evidence on the positive effects of BPR on firm performance in the literature, which was detailed in the previous sections. We therefore hypothesize:

**Hypothesis 2.** *Firm performance and productivity starts improving after the project initiation year.*

While we expect firms to derive certain benefits from their BPR implementations, such benefits may not last indefinitely, or at least their impact on firm performance and productivity may not be felt as strongly after a while. The literature on business value of IT suggests that competitive advantages gained from successful implementation of IT are difficult to sustain and that any financial advantage is short-lived [116], since competitors will eventually adopt comparable technologies to support their processes [41]. Exceptions to this rule are cases when the IT-enabled investment involves scarce resources, leverages unique processes within the organization, or is dependent on a series of antecedent investments [28]. Although the investments in IT for the purpose of supporting BPR efforts may be more difficult to imitate since the associated IT implementations potentially enable unique and proprietary business processes, we would still expect their impact on firm
performance and productivity to reduce over time in general. We thus have the following hypothesis:

**Hypothesis 3.** The positive impact of BPR projects on firm performance and productivity decreases over time.

A fourth issue of interest is the effect of project scope on firm performance. The scope of BPR projects varies considerably; 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 potentially affect the level of impact on firm productivity and performance. Empirical studies in the literature do not provide conclusive evidence on the direction of the impact. It may be that BPR projects with a large scope make the highest possible impact [10]. It may also be that the application of BPR across the enterprise does not actually produce as much benefit as a functionally-focused initiative [40]. In order to understand this issue empirically, we suggest the following hypothesis:

**Hypothesis 4.** Enterprise-wide BPR has a more negative effect during project initiation year and a more positive effect thereafter on firm performance and productivity than functionally-focused BPR.

Finally, the diversity in the functional focus of BPR projects across firms may also help explain the relationship between BPR and firm performance, since certain areas of the firm may more readily benefit from process redesign than other areas. Innovation diffusion literature provides guidance in understanding which functional areas may be associated with a higher level of improvement in firm performance due to BPR. The primary concern of innovation diffusion research is how innovations are adopted and why some innovations are adopted faster than others [5]. Rogers [107] and Tornatzky and Klein [122] identified “relative advantage”, the degree to which an innovation is perceived as better than the one it
supersedes, as one of the most important primary characteristics of innovations that help explain differences in adoption rates. The higher the relative advantage of an innovation, the more likely it is to be adopted. We believe that this principle is also at work in the context of BPR initiatives in that, the higher the relative advantage of engaging in process redesign targeting a particular functional area, the more frequently it is to be performed. Assuming that perceptions of BPR teams are rational, we would therefore expect the most frequently targeted functional areas to produce better outcomes for firms upon reengineering, and thus suggest the following hypothesis:

Hypothesis 5. The association between firm performance and BPR that impacts the more frequently targeted functional areas is greater than the average association between firm performance and BPR.

5. Data

5.1. Primary Data on Business Process Reengineering

Our research focuses on BPR projects conducted by large U.S. firms in the Fortune 500 list. We obtained the press announcements for these projects from leading news databases, ABI/INFORM, Lexis/Nexis, Business Source Complete, and Factiva, all of which together cover all prominent U.S. newspapers, professional magazines as well as business wire news. In addition, we searched through the annual reports of companies in our sample that were digitally available in Lexis/Nexis. We carried out a separate search for each company in our sample. In addition to the company name, we made sure that the word “process” appeared at least once in every article as well as one or more of the following key words: reengineer, reorganize, restructure, improve, revamp, overhaul, “process reengineering”, “process improvement”, “process redesign”, and “redesign process”. The number of articles resulting from this standard query depended on the popularity of each company. When confronted with
too many articles about a company, we narrowed the results by searching within results where one or more of the additional key words listed above was required to appear in the articles. In many cases, our standard search method and key words led us to news articles and SEC filings that discussed valid BPR projects, but we were missing some key details such as the starting year. We then looked for additional informative key words within the information sources such as a code name for a project. Using such additional key words in a second round of search for a specific company proved to be particularly useful in recovering details about a project.

Every news article that seemed to mention a specific BPR project was considered carefully. We observed that not all articles referred to such projects as BPR or reengineering. Regardless of how the projects were named in the news sources, we used the definition we adopted in Section 2 in qualifying an announcement as a valid BPR project. Two co-authors of this study independently read each BPR announcement to make sure that the description and details of the project adhered to the definition of BPR. Given our intent to measure performance effects over the years, we eliminated announcements that were not clear about the starting year of the projects. Consistent with the literature, an announcement that contained information about BPR projects at multiple firms was counted as announcements of multiple implementations, each relating to one of the firms involved [117]. When there were multiple announcements about a particular project, all of them were used to gather information about the project’s starting year and nature. We took 1998 as the baseline year and included every Fortune 500 firm of that year in our search. We used Standard and Poor’s Compustat database to extract the data for these firms. We removed 10 of these firms from our panel since they had missing or nonexistent data, reducing our sample size to 490 firms for the period between 1987 and 2008. Overall, 237 firms (48.4%) were found to have implemented BPR projects.
We also collected information about the focus of the BPR projects in terms of the functional areas being affected (or targeted) whenever such information was available. BPR projects in our sample impacted one or more of the following functional areas: accounting, customer service, finance, human resources, information technology, manufacturing, operations, purchasing, sales and marketing, and supply chain. Table 1 lists the number of BPR projects that affected each functional area. We found that manufacturing and operations was the most frequently impacted function, followed by accounting and finance. Indeed, these two areas are among the top three areas most impacted by BPR according to a 1994 survey by the consulting firm CSC Index [31], with the third area being marketing and sales. Ranganathan and Dhaliwal [105] also report manufacturing and operations to be the most frequently impacted functional area, whereas the top area according to the consulting firm Prosci is customer service (this function is ranked third in our study). The similarity between our findings and the results of previous research lends validity to this study.

[Insert Table 1 here.]

A BPR project was considered to be enterprise-wide when (i) it was explicitly referred to as being “enterprise-wide” or “company-wide” in the information source, and (ii) we had sufficient details about the project that showed that the project impacted virtually all functional areas listed in Table 1. Enterprise-wide projects involved major restructuring and strategic rethinking of business, ERP implementations coupled with comprehensive process redesign, or other substantive changes. Most projects, however, impacted either one or two functional areas, in which case we classified them as being functionally focused. Overall, 37 of the 237 projects in our data set are enterprise-wide, 111 are functionally focused, while 89 are categorized as “unclassified” since we did not have sufficiently clear information about their scope. Table 2 presents the distribution of BPR projects and their scope by industry. The industries with the highest percentage of BPR projects are construction and mining,
manufacturing, and public administration. On the other hand, the BPR projects implemented
in public administration, finance, insurance, and real estate industries are more likely to have
an enterprise-wide scope.

[Insert Table 2 here.]

5.2. Productivity and Performance Measures

We constructed various measures to calculate labor productivity, financial and operational
firm performance, stock market valuation, and firm output (all serve as dependent variables)
using standard approaches found in previous work on the business value of IT [12, 16, 17, 71,
102]. Labor productivity is calculated by dividing total sales by the number of employees.
Financial firm performance is measured by return on assets (ROA) and return on equity
(ROE). Operational performance is measured through inventory turnover, which is the cost of
goods sold divided by the total cost of inventory. Following Hitt et al. [71], we measure stock
market valuation of BPR projects by using a simplified version of Tobin’s q that relates
market value of a firm to its assets. Finally, firm output (value added) is calculated by sales
minus materials. Table 3 outlines how these measures and the control variables are
constructed.

Our regression analyses featuring various performance ratios allow us to capture a
wide variety of value creation within the firms. However, some economics and IS researchers
have expressed concern over the ability of these measures to capture future success of the
firm [12]. The ability to capture future success is especially important in our context because
it may take several years before investments in IT translate into bottom line performance
effects. Stock market valuations are less prone to this problem since they incorporate current
as well as future tangible and intangible benefits that the firm may receive. Tobin [120, 121]
proposed a measure (Tobin’s q) that incorporates stock market valuations to predict firms’
future performance, and since then analyses of this measure has been shown to improve statistical power [17]. We, therefore, include Tobin’s $q$ as an additional dependent variable in our analysis.

[Insert Table 3 here.]

5.3. Control Variables

Our model includes three firm-level control variables: firm size, advertising expenditure, and market share. Empirical studies in economics, finance, marketing, and strategy have identified these controls as key determinants of firm performance; see [23] and [118] for meta-analytic reviews. As standard in the literature, we use 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 supporting a positive relationship between advertising expenditure and firm performance [1, 30, 91, 96, 109]. Finally, market share is included as a control variable given that efficiency theory [21, 39], market power theory [87, 113], and studies on product quality assessment [111] provide evidence for a relationship between market share and firm performance. Jacobson [75] and Jacobson and Aaker [76] emphasize further that market share can serve as a proxy for other firm-specific assets not specifically captured in this study (such as managerial skill). Based on the results of previous research, we expect a positive relationship between market share and firm performance.

We control for industry at the “1 ½ digit” SIC level to eliminate variation in firm performance and productivity due to idiosyncratic characteristics of industries. We also use separate dummy variables for each year to capture transitory, economy-wide shocks that may affect firm performance [71]. The use of such dummies helps remove possible correlation between macroeconomic trends and firms’ performances during the sample period.
5.4. Descriptive Statistics

Table 4 provides descriptive statistics for our data. We deflated the following variables by using industry-specific implicit price deflators obtained from the Bureau of Labor Statistics, with the base year being 2002: sales, income, asset, equity, inventory, market value, labor cost, ordinary capital, value added, and advertising. We deflated cost of goods sold by using the Producer Price Index Industry Data obtained from the Bureau of Labor Statistics. The average firm in our sample has a market value of nearly $17 billion and annual sales of $15 billion. The market share of the average firm is close to three percent, implying that the market is relatively fragmented. The correlations among the independent variables in each regression are all significantly below 0.7, suggesting that multicollinearity does not pose a serious problem to our analyses [83].

[Insert Table 4 here.]

6. Empirical Methods

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. This formulation relies on a property of the logarithm function, and was used commonly in past research [71] as it provides flexibility in the relationship between the numerator and the denominator, while still retaining the interpretation as a performance measure. Thus, the general form of the regression models is:

\[
\begin{align*}
\log (\text{performance measure numerator})_{it} &= \text{intercept}_i + \log (\text{performance measure denominator})_{it} \\
&+ BPR \text{ implementation variables}_{it} + \text{firm controls}_{it} + \text{industry dummies}_{it} + \text{year dummies}_t + \epsilon_{it}
\end{align*}
\] (1)

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4 This property is \(\log(x/y) = \log(x) - \log(y)\).
We also perform productivity regressions based on the economic concept of production functions. Economics literature posits that firms have a production process (represented by a production function) that relates their output to various inputs. As is common in the literature, we use the Cobb-Douglas form as our production function, where value added (sales minus materials) is the output, and capital and labor are the inputs. Representing the Cobb-Douglas production function in its log-log form yields the following specification:

\[
\log \text{(value added)}_{it} = \text{intercept}_i + \log \text{(capital)}_{it} + \log \text{(labor)}_{it} + BPR \text{ implementation variables}_{it} + \text{industry dummies}_{it} + \text{year dummies}_{it} + \epsilon_{it}
\]  

(2)

Let \( t_i^{BPR} \) denote the project initiation year for firm \( i \). The BPR implementation variables in equations (1) and (2) are functions of \( t_i^{BPR} \) and include a dummy (BPR-D) that takes a value of zero until \( t_i^{BPR} \) and one thereafter, a linear term (BPR-L) that takes a value of zero until \( t_i^{BPR} \) and \( t - t_i^{BPR} \) thereafter, and a quadratic term (BPR-Q) that takes a value of zero until \( t_i^{BPR} \) and \((t - t_i^{BPR})^2\) thereafter. Recall that Hypothesis 1 is concerned with whether there is any negative impact on firm performance during project initiation. According to Hypothesis 2, we expect BPR projects to impact firm performance positively as firms adjust to and leverage their redesigned processes. However, we also expect such impact to reduce over time per Hypothesis 3. Thus, these three hypotheses suggest a negative coefficient for BPR-D, a positive coefficient for BPR-L, and a negative coefficient for BPR-Q.\(^5\) Taken together, the BPR implementation variables allow us to examine the hypothesized influence of BPR projects on firm performance and productivity. Also, BPR-L and BPR-Q jointly capture the effect of BPR projects on firm performance and productivity over time.
Recall that Hypotheses 4 and 5 are about the impact of project scope and functional focus, respectively. To test these hypotheses, each implementation variable discussed above is separated into additional variables. For example, consider a project with a functional scope. BPR-D for projects with an enterprise-wide scope is always zero, while the corresponding variable for those with a functional scope matches BPR-D for the firm. Other scope-related implementation variables as well as variables for each functional area are constructed in a similar fashion. Note that, since Hypothesis 5 is concerned with whether targeting certain functional areas with BPR is associated with a performance improvement that is above the average improvement associated with BPR, we include the original implementation and post-implementation variables in the specification of the panel data regression models when investigating the effect of projects with a specific functional focus on firm performance and productivity.

We report the results for both fixed effects (FE) and first differencing (FD), which are two standard methods that account for the unobservable firm effects (such as organizational structure and management style) that persist within observations [125, pp. 248-252]. If not accounted for, these unobservable effects correlate with the error terms leading to biased regression coefficients. FE involves time-demeaning, while FD involves differencing the data. Similar to FE, FD differences out firm-specific effects but also allows for drift of the firm-specific coefficient, whereas FE assumes that the firm-specific effects remain constant over time. The choice between FE and FD depends on the relative efficiency of the estimators. The FE estimator is more efficient if the idiosyncratic errors are serially uncorrelated, while the FD estimator is more efficient when the errors follow a random walk. According to Wooldridge [125, p. 284], the truth is likely to be somewhere in between. Since

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5 A significantly negative sign for BPR-D indicates a drop in firm performance and productivity during the project initiation year. The impact on other early years can be tested separately for \( t = t_{init} + 1, t = t_{init} + 2, \) etc.
differencing introduces autocorrelation in the error terms, we allow for correlation between the error terms for the adjacent time periods for each firm using xtgee command of Stata.

**7. Results and Discussion**

In this section, we present our panel data regression results for the specifications presented in Equations (1) and (2) above (see Tables 5-7). Different measures of firm performance and productivity are regressed on the implementation variables by controlling for various firm characteristics as well as time and industry. Please note that, for ease of exposition, we only report the coefficients and standard errors for the key implementation variables.\(^7\)

The results of our original specification in Equation (1) are presented in Table 5. As expected, firm size, advertising expenditure, and market share are generally positively associated with performance and productivity measures. Similarly, capital and labor are positively associated with firm output (value added).

**7.1. The Effect of BPR on Firm Performance and Productivity**

According to the results in Table 5, we find mixed evidence supporting Hypothesis 1. Recall that a negative coefficient for BPR-D suggests that the related performance measure drops during the project initiation year. The estimated coefficient of BPR-D is almost always negative (the only exception is when estimating labor productivity using FE), but statistically significant only when estimating ROA using FE and when estimating ROA, ROE, and value added using FD. The F-test for BPR-D + BPR-L + BPR-Q is statistically significant when estimating ROA and ROE using FD, suggesting that the negative impact is carried into the second implementation year. Finding a negative association when estimating accounting-based measures is intuitive in the sense that, since expenses related with BPR efforts and the

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\(^7\) We thank an anonymous referee for pointing this out.
redesigned processes are incurred early on, accounting-based measures can better capture the impact of such expenses.

Our FE results support Hypothesis 2. The coefficients for BPR-L in all estimations are significantly above zero, suggesting that firm productivity and performance starts improving after the project initiation year. The estimated coefficients according to FD results are also all positive, but none of them are statistically significant. This could be because of the reduced variation in our explanatory variables as a result of differencing. We should note, however, that BPR-L by itself suggests the presence of continued improvement in firm performance and productivity after project initiation into perpetuity. Therefore, it is perhaps more appropriate to consider the effect of BPR-L jointly with that of BPR-Q.

Hypothesis 3 is about the rate of improvement in firm performance and productivity associated with process reengineering. In line with the hypothesis, the estimated coefficients for BPR-Q in all estimations are negative (i.e., performance and productivity improvements slow down over time) except only when estimating Tobin’s $q$ using FD. These results are statistically significant when estimating labor productivity, ROA, ROE, and inventory turnover using FE and when estimating labor productivity and inventory turnover using FD. Furthermore, BPR-L and BPR-Q are jointly statistically significant in all FE estimations and when estimating labor productivity and inventory turnover using FD. These results underscore the importance of time and suggest that firm performance and productivity increase in a decreasing manner after project initiation.

Based on the estimated FE coefficients, firm performance comes back to pre-BPR levels in about four months (in the case of inventory turnover) to 3.5 years (in the case of ROA and value added). Note that labor productivity does not drop even during the project.

\footnote{Further details are available from the authors upon request.}
initiation year, possibly because of the automation of manual activities as part of BPR efforts. Furthermore, firm performance and productivity is estimated to improve for an extended period of about eight years (in the case of inventory turnover) to 20 years (in the case of Tobin’s $q$). The FD estimates are somewhat similar, with the notable difference that Tobin’s $q$ is estimated to never decrease after the initiation year.\footnote{Note that, according to the FE results, the coefficient for BPR-L is significantly positive while that for BPR-Q is negative but not statistically significant. According to the FD results, both coefficients are positive but not statistically significant.} There may be a number of reasons for the improvement in firm performance for an extended period. It may be that the benefits derived from BPR through the redesign of processes are in certain ways unique to each organization and therefore are difficult to imitate by competitors. Another explanation is that firms in our sample may have continued to implement complementary changes in the organization (unobservable to us) which also positively affected firm performance, perhaps as a direct consequence of their BPR projects. Given that in the case of estimating Tobin’s $q$ the long term post-implementation variable is significantly positive while that for the short term is not, we are inclined to prefer the latter explanation over the former.

Arguably, firms may be more willing to relay information about BPR projects with better outcomes, potentially leading to biased estimates. During the project initiation phase, however, firms are much less informed, although they may still have certain expectations about potential success in the future. Therefore, we have also collected information about the announcement date of each project whenever available in order to check whether the results were sensitive to when the projects were announced. Despite a much smaller sample size, the results for the restricted sample of BPR projects that were announced at most three months into project initiation are almost identical to what we have reported for the full sample in
Table 5. Also, the ordinary least squares (with Huber-White errors clustered by firm) variants of our analyses yield similar coefficients but with higher standard errors in general.

### 7.2. The Effect of Project Scope

According to Hypothesis 4, we expect BPR-related benefits and costs to be higher for enterprise-wide projects than those for functionally focused projects, all else being equal. The panel data regression results for the formulation described in Equation (2) are presented in Table 6. The coefficients for the three implementation variables should be viewed as the average net effect of the implementation of a functionally focused and enterprise-wide BPR project on the performance and productivity of the firms, respectively.

While the coefficient for BPR-D was significantly negative only when estimating ROA using FE (see Table 5), the same variable for enterprise-wide projects is significantly negative when estimating ROA, ROE, Tobin’s $q$ as well as value added. Furthermore, the difference between BPR-D coefficients for enterprise-wide and functionally focused projects is statistically significant when estimating ROA, ROE, and value added. These results are also confirmed by our FD analyses. We also never found BPR-D for functionally focused projects to be significantly less than that for enterprise-wide projects. Accordingly, our results support the notion that enterprise-wide BPR initiatives are more costly than those with a functional focus, possibly because projects with a relatively narrow scope are less likely to have a noticeable effect on firm performance.

In our FE regressions, the coefficients for BPR-L are positive in all estimations for both enterprise-wide and functionally oriented projects. The coefficient for enterprise-wide projects is significantly larger than that for functionally focused projects when estimating ROA and ROE, although the reverse is true when estimating inventory turnover. A similar comparison holds for BPR-Q; it is significantly smaller (negative) for enterprise-wide
projects than that for functionally focused projects when estimating ROA and ROE, and the reverse is true when estimating inventory turnover. Comparisons using FD do not yield statistically significant results. Hence, we do not find compelling evidence for improved firm performance after project initiation associated with enterprise-wide projects when compared with functionally oriented projects.

[Insert Table 6 here.]

7.3. The Effect of Project Focus

According to Hypothesis 5, we expect firm performance to be more positively associated with BPR projects that focus on the most frequently targeted functional areas, all else being equal. The most frequently impacted functional area in our data is manufacturing and operations followed by accounting and finance, and then by customer service. Recall that our specification includes the original implementation variables since we are concerned with whether targeting certain functional areas with BPR is associated with a performance impact above the average impact associated with BPR. Therefore, the coefficients for each functional area should be viewed as the estimated net effect in comparison to a “typical” BPR project. The regression results are presented in Tables 7a (FE results) and 7b (FD results). Note that each column in these tables represent seven regressions (one regression for each functional area).

[Insert Tables 7a and 7b here.]

According to both FE and FD results, the coefficients for BPR-D are significantly negative when estimating ROE (marketing and sales, and human resources), ROA (marketing and sales, and human resources), and Tobin’s q (customer service and human resources). The coefficients for BPR-L are generally positive for manufacturing and
operations, accounting and finance, and information technology, but statistically significant (only FE) when estimating ROE (accounting and finance), labor productivity (information technology), and inventory turnover (information technology) only. Interestingly, the coefficients for BPR-Q for information technology are significantly more negative when estimating labor productivity and inventory turnover using both FE and FD, perhaps because of the relative ease by which similar process improvements can be replicated by competing firms. Collectively, however, these results fail to provide conclusive evidence regarding the relationship between functional focus and firm performance, possibly due to sample size issues.

8. Conclusion

This paper contributes to the literature on the business value of IT as well as the growing literature on the value of BPR implementations. In order to investigate the productivity and performance effects of BPR projects, we consider a variety of measures, including labor productivity, financial ratios, operational performance, and stock market performance as measured by Tobin’s $q$. We also perform productivity regressions based on the economic concept of production functions. We perform panel data regressions using two standard methods that account for unobservable firm effects (fixed effects and first differencing) and explicitly consider the scope and focus of BPR projects in our empirical analyses. We use a comprehensive data set compiled from primary and secondary sources spanning the period between 1987 and 2008.

We find that ROA drops significantly during the project initiation year. Also, various performance and productivity measures improve (in a decreasing manner) after project initiation according to our fixed effects regressions. This result is similar in spirit to that in Hitt et al. [71] which reports improved firm productivity and performance (at a decreasing
rate) after ERP software implementations. Aral et al. [4] also report improved firm performance after, but not during, such implementations. We also find that enterprise-wide BPR projects are associated with more negative returns (as measured by ROA, ROE, and value added) during project initiation, although there is no clear evidence about their superiority over functionally focused BPR projects in terms of performance improvements after project initiation. This is in line with the observations reported in a relevant case study [40], and we believe that it reflects the risky nature of grand projects, which sometimes lead to grand failures.

Brynjolfsson et al. [19] find that IT investments have the most impact on the firm after a lag of two to three years, and suggest that because the impacts of new technology are not fully felt immediately, this may explain why earlier studies found little or no impact of IT in the same year that the investments are made. In our context, we find some evidence of negative impact on firm performance in the first year of BPR projects and that in some cases the impacts are felt immediately, especially in enterprise-wide implementations. From then on, however, we observe that some of the firm performance measures improve in a decreasing manner and peak within two to ten years in general.

There are certain limitations to this study. First, our observations are unavoidably limited to BPR projects that were publicly announced. Thus, in some cases we may have miscoded the project initiation year or the scope of projects due to missing observations about unannounced projects or extensions of announced projects. In addition, we would ideally prefer to have information on BPR-related constructs for each project such as the presence of cross-functional teams, end-user involvement in process design, etc. in order to accurately code the details of each project. Although this limitation makes the precise interpretation of the results difficult, we believe that such measurement errors make our results more conservative. Such errors would tend to bias our results toward finding no effect of BPR or
no difference between enterprise-wide and functionally focused projects due to the random error in our coding. Second, firms may be more inclined to announce more successful projects than less successful ones, which may potentially bias the estimates, although our results on the restricted sample of projects that were announced early on suggest that this may not be a serious concern. Third, because we have primarily focused on large U.S. firms, our results may not apply to small and medium-sized businesses and firms around the world. Fourth, our results capture the effect of BPR averaged over a wide variety of firms and their projects. Although we report a significant association between improved firm performance and BPR implementations for certain performance and productivity measures, it is conceivable that some of these projects may not have led to any performance gains. Finally, firm performance may be influenced by numerous other factors, many of which are not easily observable, and these factors may potentially reduce the precision of the estimates or bias the estimates if their effects are not removed by the time dummies and other control variables. The utilization of both cross sectional and time series nature of our data helps alleviate this issue for firm specific factors that are constant over time, since a primary motivation for using panel data is to address the omitted variables problem [125].

There are interesting avenues for future research in this subject area. Effectiveness of IT applications, especially BPR implementations, may not be uniform across all activities of a firm. Therefore, our firm-level analysis can be extended to analyze the effects of BPR at the strategic business unit of firms. This would be possible by defining new productivity and performance measures for different business units and comparing the resulting differences across them. Such an analysis may provide further and more specific insights about the design and value of BPR initiatives to the managers of the individual business units. Moreover, adopting a process-oriented model may help researchers observe the effects of
BPR on other intermediate-level productivity variables, such as capacity utilization and relative quality [6].

ACKNOWLEDGMENTS: We thank Jason Abrevaya (University of Texas), Bill Even (Miami University), Mehmet Ozbilgin (City University of New York), Sumit Sircar (Miami University), three anonymous referees, and the Editor-in-Chief, Vladimir Zwass, for their valuable suggestions and comments. All remaining errors are our own.

References


32. Cummings, J. Reengineering is high on list, but little understood. *Network World*, 27 July (1992), 27.


### Table 1. Number of projects that impacted each functional area

<table>
<thead>
<tr>
<th>Industry</th>
<th>No of firms with BPR projects</th>
<th>Percent BPR</th>
<th>Percent enterprise-wide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture, Forestry, and Fishing</td>
<td>0</td>
<td>0%</td>
<td>-</td>
</tr>
<tr>
<td>Construction and Mining</td>
<td>7</td>
<td>64%</td>
<td>0%</td>
</tr>
<tr>
<td>Finance, Insurance, and Real Estate</td>
<td>31</td>
<td>36%</td>
<td>29%</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>110</td>
<td>57%</td>
<td>15%</td>
</tr>
<tr>
<td>Public Administration</td>
<td>3</td>
<td>60%</td>
<td>33%</td>
</tr>
<tr>
<td>Retail Trade</td>
<td>24</td>
<td>46%</td>
<td>13%</td>
</tr>
<tr>
<td>Services</td>
<td>10</td>
<td>37%</td>
<td>10%</td>
</tr>
<tr>
<td>Transportation, Communications, and Utilities</td>
<td>36</td>
<td>48%</td>
<td>8%</td>
</tr>
<tr>
<td>Wholesale Trade</td>
<td>15</td>
<td>47%</td>
<td>27%</td>
</tr>
<tr>
<td><strong>Total/Overall</strong></td>
<td><strong>237</strong></td>
<td><strong>48%</strong></td>
<td><strong>27%</strong></td>
</tr>
</tbody>
</table>

### Table 2. Distribution of BPR projects across industries

<table>
<thead>
<tr>
<th>Functional Area</th>
<th>Number of BPR Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing and Operations</td>
<td>74</td>
</tr>
<tr>
<td>Accounting and Finance</td>
<td>60</td>
</tr>
<tr>
<td>Customer Service</td>
<td>57</td>
</tr>
<tr>
<td>Information Technology</td>
<td>56</td>
</tr>
<tr>
<td>Supply Chain</td>
<td>49</td>
</tr>
<tr>
<td>Marketing and Sales</td>
<td>47</td>
</tr>
<tr>
<td>Human Resources</td>
<td>39</td>
</tr>
<tr>
<td>Variables</td>
<td>Description</td>
</tr>
<tr>
<td>--------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Performance Measures</strong></td>
<td></td>
</tr>
<tr>
<td>Labor productivity</td>
<td>Numerator: Sales; Denominator: Number of employees. Higher ratio indicates more productivity per employee.</td>
</tr>
<tr>
<td>Return on assets (ROA)</td>
<td>Numerator: Pretax income; Denominator: Assets. Higher ratio indicates more profit per unit asset.</td>
</tr>
<tr>
<td>Return on equity (ROE)</td>
<td>Numerator: Pretax income; Denominator: Equity. Higher ratio indicates a high return accruing to the common shareholders.</td>
</tr>
<tr>
<td>Inventory turnover</td>
<td>Numerator: Cost of goods sold; Denominator: Inventory. Higher ratio indicates efficient inventory management.</td>
</tr>
<tr>
<td>Tobin’s q</td>
<td>Numerator: Market value; Denominator: Assets. Higher ratio indicates high stock market return per unit asset.</td>
</tr>
<tr>
<td>Value added</td>
<td>Firm output measured by sales minus materials</td>
</tr>
<tr>
<td><strong>Firm Controls</strong></td>
<td></td>
</tr>
<tr>
<td>Firm size</td>
<td>Number of employees</td>
</tr>
<tr>
<td>Advertising</td>
<td>Advertising expense</td>
</tr>
<tr>
<td>Market share</td>
<td>Annual sales of a firm divided by the total annual sales of all available firms within the firm’s primary industry at the 2-digit Standard Industrial Classification (SIC) level</td>
</tr>
</tbody>
</table>

*Table 3. Description of variables*
<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales a</td>
<td>14,948</td>
<td>26,202</td>
</tr>
<tr>
<td>Pretax income a</td>
<td>778</td>
<td>2,118</td>
</tr>
<tr>
<td>Cost of goods sold b</td>
<td>9,127</td>
<td>17,580</td>
</tr>
<tr>
<td>Market value a</td>
<td>17,041</td>
<td>34,548</td>
</tr>
<tr>
<td>Assets a</td>
<td>31,938</td>
<td>98,290</td>
</tr>
<tr>
<td>Equity a</td>
<td>5,441</td>
<td>10,073</td>
</tr>
<tr>
<td>Inventory a</td>
<td>2,275</td>
<td>13,705</td>
</tr>
<tr>
<td>Value added a</td>
<td>4,036</td>
<td>7,170</td>
</tr>
<tr>
<td>Labor cost a</td>
<td>3,842</td>
<td>5,075</td>
</tr>
<tr>
<td>Ordinary capital a</td>
<td>10,172</td>
<td>19,755</td>
</tr>
<tr>
<td>Advertising a</td>
<td>513</td>
<td>828</td>
</tr>
<tr>
<td>Employees</td>
<td>60,747</td>
<td>106,592</td>
</tr>
<tr>
<td>Market share</td>
<td>0.029</td>
<td>0.077</td>
</tr>
</tbody>
</table>

a Values in millions of 2002 dollars

b Values in millions of dollars (the base year varies by industry)

Table 4. Descriptive statistics.
### Table 5. Comparisons of firm performance and productivity

<table>
<thead>
<tr>
<th>Interpretation</th>
<th>Firm Performance</th>
<th>Firm Productivity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>log (sales)</td>
<td>log (pretax income)</td>
</tr>
<tr>
<td>Labor productivity</td>
<td>Return on assets (ROA)</td>
<td>Return on assets (ROA)</td>
</tr>
<tr>
<td>FE BPR-D</td>
<td>0.0055 (0.0142)</td>
<td>-0.0466* (0.0202)</td>
</tr>
<tr>
<td>BPR-L</td>
<td>0.0213*** (0.0039)</td>
<td>0.0158** (0.0054)</td>
</tr>
<tr>
<td>BPR-Q</td>
<td>-0.0012*** (0.0003)</td>
<td>-0.0009* (0.0004)</td>
</tr>
<tr>
<td>FD BPR-D</td>
<td>-0.0074 (0.0100)</td>
<td>-0.0983*** (0.0304)</td>
</tr>
<tr>
<td>BPR-L</td>
<td>0.0045 (0.0078)</td>
<td>0.0180 (0.0141)</td>
</tr>
<tr>
<td>BPR-Q</td>
<td>-0.0012* (0.0005)</td>
<td>-0.0012 (0.0009)</td>
</tr>
</tbody>
</table>

*** p<0.001; ** p<0.01; * p<0.05. Numbers in parentheses are corresponding robust standard errors.

FE: Fixed effects; FD: First differencing

Control variables: Firm size, advertising, market share, industry dummies, and year dummies (performance regressions); capital, labor, industry dummies, and year dummies (productivity regressions).
<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Log (sales)</th>
<th>Log (pretax income)</th>
<th>Log (pretax income)</th>
<th>Log (cost of goods sold)</th>
<th>Log (market value)</th>
<th>Log (value added)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interpretation</td>
<td>Labor productivity</td>
<td>Return on assets (ROA)</td>
<td>Return on equity (ROE)</td>
<td>Inventory turnover</td>
<td>Tobin's q</td>
<td>Value added</td>
</tr>
<tr>
<td>BPR-D</td>
<td>-0.0471** (0.0182)</td>
<td>-0.0193 (0.0254)</td>
<td>-0.0225 (0.0244)</td>
<td>-0.0340 (0.0187)</td>
<td>-0.0221 (0.0205)</td>
<td>0.0061 (0.0114)</td>
</tr>
<tr>
<td>Functional</td>
<td>BPR-L</td>
<td>0.0253*** (0.0053)</td>
<td>0.0041 (0.0073)</td>
<td>0.0026 (0.0070)</td>
<td>0.0278*** (0.0053)</td>
<td>0.0147* (0.0059)</td>
</tr>
<tr>
<td></td>
<td>BPR-Q</td>
<td>-0.0020*** (0.0004)</td>
<td>-0.0004 (0.0005)</td>
<td>-0.0002 (0.0003)</td>
<td>-0.0020*** (0.0003)</td>
<td>-0.0006 (0.0004)</td>
</tr>
<tr>
<td>Enterprise-wide</td>
<td>BPR-D</td>
<td>-0.0242 (0.0312)</td>
<td>-0.1568*** (0.0451)</td>
<td>-0.1502*** (0.0440)</td>
<td>0.0224 (0.0348)</td>
<td>-0.0748* (0.0354)</td>
</tr>
<tr>
<td></td>
<td>BPR-L</td>
<td>0.0204* (0.0085)</td>
<td>0.0368*** (0.0120)</td>
<td>0.0452*** (0.0117)</td>
<td>0.0061 (0.0093)</td>
<td>0.0166 (0.0095)</td>
</tr>
<tr>
<td></td>
<td>BPR-Q</td>
<td>-0.0011* (0.0006)</td>
<td>-0.0024** (0.0008)</td>
<td>-0.0028*** (0.0007)</td>
<td>0.0002 (0.0006)</td>
<td>-0.0007 (0.0006)</td>
</tr>
<tr>
<td>FD</td>
<td>BPR-D</td>
<td>-0.0047 (0.0138)</td>
<td>-0.0117 (0.0411)</td>
<td>-0.0066 (0.0397)</td>
<td>-0.0009 (0.0171)</td>
<td>-0.0035 (0.0223)</td>
</tr>
<tr>
<td></td>
<td>BPR-L</td>
<td>0.0199* (0.0095)</td>
<td>0.0105 (0.0171)</td>
<td>0.0023 (0.0165)</td>
<td>0.0248* (0.0114)</td>
<td>0.0092 (0.0127)</td>
</tr>
<tr>
<td></td>
<td>BPR-Q</td>
<td>-0.0020** (0.0006)</td>
<td>-0.0003 (0.0012)</td>
<td>-0.0001 (0.0011)</td>
<td>-0.0023** (0.0007)</td>
<td>-0.0002 (0.0008)</td>
</tr>
<tr>
<td>Enterprise-wide</td>
<td>BPR-D</td>
<td>-0.0045 (0.0240)</td>
<td>-0.3230*** (0.0744)</td>
<td>-0.3138*** (0.0725)</td>
<td>-0.0108 (0.0311)</td>
<td>-0.0574 (0.0400)</td>
</tr>
<tr>
<td></td>
<td>BPR-L</td>
<td>-0.0004 (0.0161)</td>
<td>0.0472 (0.0343)</td>
<td>0.0467 (0.0331)</td>
<td>-0.0118 (0.0191)</td>
<td>0.0023 (0.0218)</td>
</tr>
<tr>
<td></td>
<td>BPR-Q</td>
<td>-0.0003 (0.0011)</td>
<td>-0.0031 (0.0027)</td>
<td>-0.0029 (0.0026)</td>
<td>0.0007 (0.0013)</td>
<td>0.0007 (0.0015)</td>
</tr>
</tbody>
</table>

*** p<0.001; ** p<0.01; * p<0.05. Numbers in parentheses are corresponding robust standard errors.

**FE: Fixed effects; FD: First differencing**

Control variables: Firm size, advertising, market share, industry dummies, and year dummies (performance regressions); capital, labor, industry dummies, and year dummies (productivity regressions).

Table 6. Comparisons of firm performance and productivity by project scope
## Table 7a. Regression results for the effect of functional focus (fixed effects)

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Firm Performance</th>
<th>Firm Productivity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>log (sales)</td>
<td>log (pretax income)</td>
</tr>
<tr>
<td><strong>M&amp;O</strong></td>
<td>-0.0163 (0.0259)</td>
<td>-0.0668 (0.0369)</td>
</tr>
<tr>
<td><strong>A&amp;F</strong></td>
<td>0.0065 (0.0278)</td>
<td>-0.0755 (0.0395)</td>
</tr>
<tr>
<td><strong>CS</strong></td>
<td>-0.0180 (0.0284)</td>
<td>-0.0607 (0.0406)</td>
</tr>
<tr>
<td><strong>IT</strong></td>
<td>-0.0899** (0.0286)</td>
<td>-0.0684 (0.0412)</td>
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<tr>
<td><strong>SC</strong></td>
<td>-0.0271 (0.0294)</td>
<td>-0.0524 (0.0419)</td>
</tr>
<tr>
<td><strong>M&amp;S</strong></td>
<td>-0.0075 (0.0305)</td>
<td>-0.1016* (0.0441)</td>
</tr>
<tr>
<td><strong>HR</strong></td>
<td>-0.0123 (0.0327)</td>
<td>-0.1158* (0.0469)</td>
</tr>
<tr>
<td><strong>M&amp;O</strong></td>
<td>0.0003 (0.0076)</td>
<td>0.0162 (0.0107)</td>
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<tr>
<td><strong>A&amp;F</strong></td>
<td>0.0052 (0.0080)</td>
<td>0.0198 (0.0111)</td>
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<tr>
<td><strong>CS</strong></td>
<td>-0.0078 (0.0080)</td>
<td>0.0123 (0.0111)</td>
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<tr>
<td><strong>M&amp;S</strong></td>
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<td>0.0264* (0.0126)</td>
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<tr>
<td><strong>HR</strong></td>
<td>-0.0014 (0.0091)</td>
<td>0.0286* (0.0128)</td>
</tr>
<tr>
<td><strong>M&amp;O</strong></td>
<td>0.0008 (0.0005)</td>
<td>-0.0012 (0.0007)</td>
</tr>
<tr>
<td><strong>A&amp;F</strong></td>
<td>-0.0001 (0.0005)</td>
<td>-0.0014 (0.0008)</td>
</tr>
<tr>
<td><strong>CS</strong></td>
<td>0.0009 (0.0005)</td>
<td>-0.0010 (0.0007)</td>
</tr>
<tr>
<td><strong>M&amp;S</strong></td>
<td>-0.0034*** (0.0005)</td>
<td>-0.0007 (0.0008)</td>
</tr>
<tr>
<td><strong>HR</strong></td>
<td>0.0004 (0.0006)</td>
<td>-0.0020* (0.0008)</td>
</tr>
</tbody>
</table>

M&O: Manufacturing and operations; A&F: Accounting and finance; CS: Customer service; IT: Information technology; SC: Supply chain; M&S: Marketing and sales
Control variables: Firm size, advertising, market share, industry dummies, and year dummies (performance regressions); capital, labor, industry dummies, and year dummies (productivity regressions).
<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Firm Performance</th>
<th>Firm Productivity</th>
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<tbody>
<tr>
<td></td>
<td>log (sales)</td>
<td>log (pretax income)</td>
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<tr>
<td>M&amp;O</td>
<td>-0.0129 (0.0201)</td>
<td>-0.0245 (0.0613)</td>
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<tr>
<td>A&amp;F</td>
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<tr>
<td>IT</td>
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<td>-0.2181** (0.0656)</td>
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<tr>
<td>SC</td>
<td>0.0044 (0.0228)</td>
<td>-0.1345* (0.0684)</td>
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<tr>
<td>M&amp;S</td>
<td>0.0018 (0.0235)</td>
<td>-0.2245** (0.0751)</td>
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<td>HR</td>
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<td>-0.2550*** (0.0771)</td>
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<tr>
<td>M&amp;O</td>
<td>-0.0033 (0.0132)</td>
<td>0.0174 (0.0262)</td>
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<tr>
<td>A&amp;F</td>
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<td>0.0040 (0.0278)</td>
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<td>0.0095 (0.0257)</td>
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<tr>
<td>IT</td>
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<td>0.0353 (0.0270)</td>
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<tr>
<td>SC</td>
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<td>-0.0092 (0.0296)</td>
</tr>
<tr>
<td>M&amp;S</td>
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<td>0.0123 (0.0337)</td>
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<td>HR</td>
<td>-0.0109 (0.0168)</td>
<td>0.0327 (0.0340)</td>
</tr>
<tr>
<td>M&amp;O</td>
<td>0.0014 (0.0009)</td>
<td>-0.0003 (0.0019)</td>
</tr>
<tr>
<td>A&amp;F</td>
<td>0.0008 (0.0010)</td>
<td>-0.0001 (0.0020)</td>
</tr>
<tr>
<td>CS</td>
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<td>-0.0002 (0.0017)</td>
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<tr>
<td>IT</td>
<td>-0.0039*** (0.0010)</td>
<td>-0.0032 (0.0020)</td>
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<tr>
<td>SC</td>
<td>0.0010 (0.0010)</td>
<td>0.0006 (0.0023)</td>
</tr>
<tr>
<td>M&amp;S</td>
<td>0.0011 (0.0011)</td>
<td>-0.0014 (0.0027)</td>
</tr>
<tr>
<td>HR</td>
<td>0.0010 (0.0012)</td>
<td>-0.0029 (0.0026)</td>
</tr>
</tbody>
</table>

M&O: Manufacturing and operations; A&F: Accounting and finance; CS: Customer service; IT: Information technology; SC: Supply chain; M&S: Marketing and sales
Control variables: Firm size, advertising, market share, industry dummies, and year dummies (performance regressions); capital, labor, industry dummies, and year dummies (productivity regressions).

Table 7b. Regression results for the effect of functional focus (first differencing)