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# THE ROLES OF IT IN PHYSICAL AND INFORMATION PRODUCT INDUSTRIES: TESTING A CONTINGENCY MODEL OF THE IT-PRODUCTIVITY RELATIONSHIP

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## ABSTRACT

While empirical findings indicate that the IT-productivity relationship varies by industry, review research notes the lack of conceptual and empirical studies explaining these differences [39]. This paper conceptualizes an industry-level variable that is crucial to the IT-Productivity relationship: whether an industry produces physical products or information products. As IT is primarily used for information processing [18], industries that make products composed of information have very different IT effects from those that produce products composed of physical materials, and this may be the most important difference in IT effects between industries [48]. The few papers in this area study the IT-Productivity link at the industry or sector level, and find that information product industries have less of a link between IT and productivity than physical product industries. Drawing upon the information-processing view [18] and the concept of industry information-intensity [48], we hypothesize that this link should be in the opposite direction. Our empirical tests using a seven-year dataset find two differences in IT intensity between the two types of industries: Information product industries are not only more IT intense, but the variance in IT intensity is much higher than in physical product industries. In addition, we find that the firm-level IT-Productivity relationship is much stronger in information product industries than in physical product industries, in contrast with prior industry and sector level studies.

**Keywords:** IT spending, firm productivity, information products, physical products

## INTRODUCTION

As firm IT spending increased to 50% of capital expenditures in the late 1990s (from 5% in the 1960s) [12], researchers have searched for evidence of its benefits to firm performance, through a large-scale field experiment [16], theory [39], [18], [48], [13], [26], [29], [35], [37], empirical work [1], [3], [4], [5], [7], [9], [11], [15], [21], [22], [23], [30], [33], [36], [41], [47], [58], [60], [61], [62], [65], [67], [72], [14], [20], [34], [70], and found empirical evidence that IT improves firm-level productivity [7], [22].

In a comprehensive review research article, Melville et al. [39] synthesized the work in this area into an integrative model on IT Business value, in which they explicitly model the contingent effects of the industry. Their detailed review of empirical studies on IT Business

Value reveals that few studies directly examine the differential effects of IT across industries [23], [8], [32], [43], [63], [64], [45], and even fewer provide a conceptual basis for such differences to exist. Melville et al. then develop an agenda for future research by synthesizing their findings into the following proposition: "Industry characteristics moderate the ability of firms to apply IT for improved organizational performance and to capture the resulting benefits." They also note that existing research knows "very little about particular industry characteristics and their association with IT Business Value" and "conceptual understanding of why such differences exist is very limited" [39, pp. 305].

The most important conceptual difference between industries in regards to IT effects may be whether they produce products composed of information or whether they produce products composed of physical materials [48]. Industries whose primary product is information, such as the retail banking or insurance industry have vastly different IT effects than other industries where the primary products are goods composed of physical materials, which include industries that make furniture, clay, wood, rubber and textile products [48]. As the primary role of information technology in a firm is to enhance information processing [18], this difference between industries may be a critical factor in the IT-productivity relationship, since IT should arguably have very different effects in industries in which the main task of firms is to produce and process information [48]. In this study, we propose to answer Melville et al.'s call to model contingent effects of the industry on the IT-Firm Performance relationship [39] by examining the contingent effects of two different types of industries: Information Product Industries (IPI) vs. Physical Product Industries (PPI). Specifically, we seek to answer these two research questions:

- What are the differences in IT intensity between IPI and PPI?
- How does the IT–productivity relationship for a firm vary between IPI and PPI?

We address these research questions and contribute to the continuing research tradition by building on conceptual differences between information product and physical product industry types to examine effects in the direction opposite to earlier empirical findings [23]. We hypothesize and empirically verify that IPI are not only more IT intensive than PPI, they also have a higher variance in IT intensity than PPI, showing that they have not reached the state that Hu & Quan use to explain their results [23]. In addition, we show that at the firm level, IT intensity actually has a much stronger link with productivity in IPI than PPI. This contributes by providing empirical support to some of Porter & Millar's arguments on industry information intensity [48]. Evidence generated could facilitate more granulated theoretical development of the IT-firm productivity link, and allows us to develop implications for practice. Finally, we address previous methodological limitations by improving variable operationalizations, incorporating time-lags, and operationalizing variables that are neutral to price deflators.

## LITERATURE REVIEW

Contingency variables for IS success in organizations has been a major concern for researchers from over 30 years ago [17]. A recent review and synthesis of the literature led Melville et al. to formulate a theoretical model of IT Business Value which proposes that the industry that a firm operates in has contingent effects on the IT to firm productivity relationship [39]. Some progress has indeed been made recently in this direction [19], [66], [38], [46], [42]. For example, in a study that only looks at manufacturing industries, Mittal & Nault [42] find that IT-Intensive manufacturing industries have more indirect effects of IT, while in non-IT-Intensive manufacturing industries, direct effects predominate. However, after a thorough review of over 200 peer-reviewed journal articles on IT Business Value, Melville et al. [39] conclude that there is very little conceptual or empirical work on such contingent effects. They also note "empirical studies of IT business value typically include variables to control for industry effects" (e.g., see [51]). Melville et al. identify a gap in this area, as "by including such controls, researchers are able to more accurately identify those impacts associated with IT versus those being driven by industry factors. However, the use of industry controls does not address the issue of how industry characteristics constrain or promote the ability of competing firms to apply IT for organizational improvement" [39, pg. 304].

When it comes to IT effects, possibly the most crucial conceptual difference between industries is whether the industry produces products composed of information such as retail banks, insurance companies, investment banks, or whether the industry produces products composed of physical materials such as food, clothing or furniture [48]. As the primary task of IT in a firm is to process information, industries that produce information products may have vastly different IT effects from those that produce physical products. In information product industries, processing information is their main task, and these industries may have very different IT needs as well as IT effects. However, there is very little empirical research on this contingent effect of the industry.

Further, operationalization of variables has been a challenge for researchers in this area. Researchers report both positive as well as negative results for the IT-performance link with different operations of variables [15], [36], [47], [62]. In this study, we attempt to address this challenge by linking variable operationalizations to the theoretical framework underlining the hypothesis [4]. We build on our theoretical framework to posit that IT primarily empowers employees to improve the firm's labor productivity. Based on this theoretical framework, as discussed in more details later, we choose IT Intensity (IT budget per employee) as the independent variable, and Firm Productivity (revenue per employee) as the dependent variable. In addition, IT spending requires time to show benefits [44], [10], indicating the need for time lags.

## RESEARCH MODEL AND HYPOTHESIS

To address gaps in the literature discussed above, we first conceptualize a contingency variable that may be the primary difference between industries with respect to the IT-productivity relationship: whether the industry makes physical product or information products [48]. According to Porter & Millar's concept of product and process information intensity [48], firms exist not only to produce products and services, they also have to conduct processes to coordinate all the activities of their value chains and supply chains. For example, an auto manufacturer needs to manufacture cars, but their employees also have to process a lot of information around these cars, including all the orders they get from their auto dealers, the parts they have in inventory, the make, model, colors of the cars they have in stock, information on lead times for each part from different suppliers, predictions and demand forecasts, etc. However, even if an auto manufacturer has very efficient information-processing capabilities, it still has to manufacture its cars, i.e., employees need to press the steel plates, assemble the car from its component parts including engines, transmissions, wheels, seats, steering wheels, and so on. For processing the product itself, however, their employees' needs are more towards industrial technologies for processing the physical material of the product. This is similar for most companies that produce physical products.

However, many companies produce products that are primarily composed of information [48], like insurance, banks, financial services, credit and loans, investments, currency trading, etc. Like companies that produce physical products, employees in these firms also need IT to process information around their product, such as orders, customers, partners, competitors, its internal value chain activities, capital needs, human resource needs, demand predictions; and customer satisfaction, etc. However, employees in these firms have an additional need for IT to process their product itself, since their product is composed primarily of information. Employees of these companies need IT to process insurance claims, conduct banking transactions, do financial analysis, execute stock trades, get credit histories, analyze movements of international currencies relative to each other etc. Therefore, employees in IPI firms may have higher needs for IT than employees in PPI firms. We label the term, IT investment per employee, as the "IT Intensity" of the firm.

In this hypothesis, it is assumed that the IT intensity required to process information around the product is somewhat similar between IPI and PPI firms, and that the IT intensity required to process the product itself is an additional need for IPI firms. However, it is possible that the IT intensity required to process information around the product is greater in PPI than in IPI. It is also possible that the IT used in IPI to process the product could also be used to process the information around the product. If either or both of these possibilities are true, then PPI may have similar or greater IT intensities than PPI firms. A review of the literature confirms that differences in IT Intensities between firms in PPI and those in IPI have not been formally tested before. Thus, we posit that at an average, IPI firms are more IT intensive than PPI firms in our first hypothesis:

*H1: IT intensity of firms in information product industries is higher than that of firms in physical product industries.*

In the earlier section, we discussed firms' need for technology to enable their employees to process their product itself as well as to process information around the product related to customers, suppliers, inventory, value chain activities, R&D, etc. [48]. While employees need IT for the latter, for processing the product itself employees may need either traditional industrial technology or modern information technology, depending on whether the company makes physical products or information products, respectively. Since the industrial revolution, firms making physical products have evolved toward relatively standardized processes in its use of mechanical technology. However, modern information technologies have been around for a much shorter period of time, and these firms are still coming up with new and innovative ways of using IT to process their information products. In addition, there is also a difference in the pace of change of the technologies themselves. Information Technology has been going through rapid changes since the 1950s, and in the decades since 1950, the pace of change of these technologies has increased, not decreased. On the other hand, mechanical technologies do not experience as rapid a pace of change than of information technology. Due to these two reasons, we posit that firms that make information products will have highly varied investments to fulfill their employees' IT needs to process their information products. Therefore, firms in IPI can be expected to have a higher variance in firm IT intensities than firms in PPI. This is in contrast to Hu & Quan's reasoning that the financial sector, which includes several IPI like retail banks, commercial banks, insurance, trading and investments, have extracted all they can from IT and are now very mature and stable in their IT applications [23]. Hence, we propose our next hypothesis:

*H2: The variance in IT Intensities is higher among firms in information product industries than in physical product industries.*

Previous research has theorized that IT spending can affect firm-level productivity and this IT-productivity relationship is supported by empirical studies, e.g. [7], [22]. For our second research objective, we examine if this relationship varies depending on contingency effects of the nature of the product of the industry, as this may be the most important difference between the IT effects of industries [48].

As discussed earlier, productivity of a firm can be increased in two ways: first, by improving the processing of the firm's product itself, and second, by improving the processing of information in handling the product throughout the value chain. Compared to industries with physical products such as food, petroleum, or chemicals, IT can have a greater effect on processing of the product in industries whose products composed primarily of information, such as insurance, banking, or financial services. For these industries, IT can help employees by automating a lot of the information processing of the product itself, allowing more work to be done by fewer employees. If an insurance company employee needs several hours to process a claim, IT can automate a lot of the processing, allowing the employee to process the claim much faster and more accurately. For example, Allstate Insurance Company's operations consist almost entirely of information processing, and IT has helped to improve its productivity drastically by redesigning and automating the claim processing systems throughout the company [71]. By contrast, in industries that make physical products such as canned food, although IT can affect employee productivity, it may not be to the same extent, as employees still need to do the required physical processing. However, in both types of industries, IT can improve the information processing regarding the value chain and the supply chain [48]. For example, employees of Frito-Lay, even though they deal with food products, still have to process orders, deliveries, confirmations and payments. The use of an information system automated this information processing, enabling their employees to handle a larger volume of sales [37], and therefore empowering their employees to be more productive.

However, the very little empirical research in this area finds results that contradict this reasoning. An industry-level analysis of productivity by Hu & Quan [23] indicates that for industries that make physical products, IT has a stronger relationship with productivity than average, while in industries that make financial products, IT has no relationship with productivity. In a similar vein, Olazabel [45] finds that in the retail banking industry, labor productivity growth decreased while IT intensity growth increased. These findings suggest that in IPI, such as retail banking, the effect of IT on productivity may be lower than that in the PPI, such as various manufacturing industries. Hu & Quan [23] explain their findings by saying that financial firms were among the first to adopt IT innovations for operational and strategic purposes, and before the time period of their study, 1970-1999, financial firms already had mature IT systems (in direct contrast with our previous hypothesis) and had extracted all possible productivity benefits from IT. They believe this may explain why the IT productivity link is more pronounced in the manufacturing sector than in the financial sector [23].

An alternate explanation may be that the level of analysis obscures the relationship. As this distinction is important to this study, we define the use of these terms in this paper: Sector refers to a large segment of the economy, such as mining or public services; while industry refers to a much more specific group of companies or businesses, such as asset management, petroleum refining, retail banking, or chemical production. Stiroh [63] finds that the IT-productivity link becomes more discernable at more granulated levels of analysis, but disappears at more aggregated levels. Stiroh finds no link between IT and productivity at the level of the entire economy, but when the analysis is repeated at the sector level, a few sectors show a significant link between IT and productivity. For some other sectors, the IT-productivity relationship only becomes discernable when the analysis is repeated at the industry level, in which some industries become significant [63]. Therefore, we posit that in some industries and sectors, the IT-Productivity link is less visible at an industry or sector level analysis, and may only become visible at the level of the firm. Hu & Quan state this is a limitation of their study [23], and may be the reason they did not find a significant link in the financial sector, in which several industries produce information products. It is possible that industry or sector level factors can obscure this relationship. Mittal & Nault [42] also state this as a limitation of their study.

For example, additional government regulations (like Sarbanes-Oxley) in some industries may dictate hiring additional employees for compliance, reducing labor productivity industry wide. In addition, these regulations may require additional IT investments to support all the additional work employees need to perform. The net effect may be that IT investments per employee may have gone up, but employee productivity may not have changed much, or even reduced, depending on the additional workload generated by the regulation. However, as all firms in the industry will be subject to the same regulations, we may be able to discern the link at the firm level. For example, although two competing firms in the industry may be subject to the same regulations in a particular year, one firm may have additional IT investments to support employee productivity as compared to its competitor. If this increases the firm's employee productivity, we should see that this firm has relatively higher employee productivity than the competing firm that is less IT intense. Therefore, each firm must be compared only to other firms in their industry in the same year. This analysis between competitors may enable us to see relationships that can be obscured at the industry or sector level. Thus, even though an industry-level analysis may be appropriate for industry differences on a single variable (like IT intensity), a more granulated level of analysis may be needed to uncover differences in relationships such as the IT-Productivity link.

Therefore, our postulate in this study is different from Hu and Quan's study. We are not comparing differences in sector-level or industry-level productivity caused by IT, as sector-level or industry level productivity may be inherently different across sectors and industries, and may be affected by industry or sector level effects such as regulation, downturns or substitution from other industries. Instead, we posit that within a single industry, firms can gain productivity increases relative to other firms within the same industry, by empowering their employees with IT. Therefore, for this hypothesis, we define the notion of 'Relative IT Intensity' as the IT investment per employee made by a firm relative to that firm's competitors in its industry in the same year. Similarly, we define 'Relative Firm Productivity' as the firm's output per employee relative to its competitors in the same industry in the same year. As posited earlier, firm IT intensities may vary widely depending on the industry the firm is in. Firm strategies may also vary between industries and between years. Therefore, we only compare each firm to its competitors – other firms in the same industry in that year. In this context, as depicted by the research model in Figure 1, we hypothesize in H3 that the effect of relative IT intensity on relative productivity depends on whether the firm makes information products or physical products:

*H3: Firms' Relative IT Intensity will be more positively related to their Relative Productivity for firms in information product industries than those in physical product industries.*

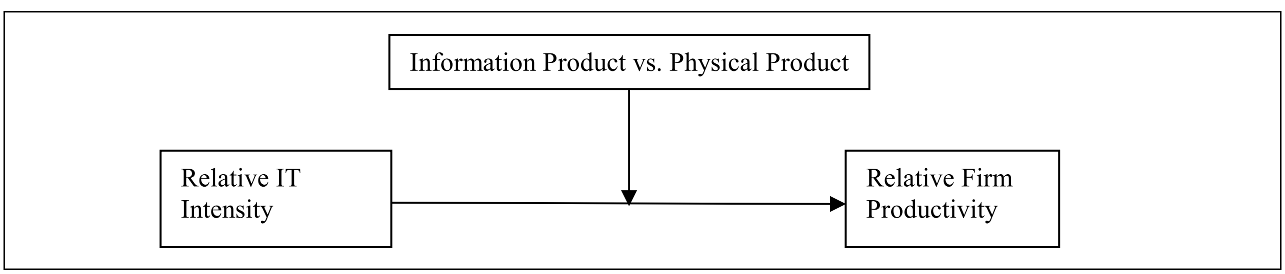


Figure 1: Research Model

Note that for H1 and H2, we do industry-level analysis, i.e., we compare means and variance of two types of industries. For H3, however, the analysis is at the firm level. An individual firm's relative IT intensity (as a z-score relative to its competitors in the same industry for a specific year) will be related to the firm's relative productivity (also in terms of a z-score relative to its competitors in the same industry for a specific year). While H1 and H2 compare absolute IT intensity, H3 examines relative IT intensity. Also, note that the moderator in the research model (Figure 1) is not related to the independent variable [2]. In fact, as z-scores, the independent variable follows a normal distribution within a given industry regardless whether the industry makes information products or physical products.

# METHODOLOGY

We collect data to test the hypothesis in this study using secondary sources, including IT budgets from InformationWeek magazine matched to firm level data from Standard & Poor's Compustat database. Data on IT budgets was gathered from InformationWeek magazine's website. InformationWeek magazine publishes an annual survey of 500 firms called the InformationWeek 500, in which it collects data on IT practices of various large firms in the United States, and derives the annual ranking of the 500 most innovative users of business technology in the nation based on the magazine editors' criteria for evaluation [24], [25]. This information resource has been used in previous studies [4], [5], [58]. This data is collected through an extensive mail, phone, and fax survey of large firms with annual revenue that could be verified against external sources. As part of this survey, data on IS budgets is also collected from the respondents.

As data on IS budgets is difficult to obtain, IS research frequently uses data sets from prior decades for testing theory [4]-[5], [23], [33], [27]. Publicly available datasets on IT spending at the industry level range from the 1950s to the 1990s. At the firm level, there are only two publically available datasets with IS Budget data [53]: one was collected by International Data Group and published in ComputerWorld magazine and the second is the InformationWeek 500, with the InformationWeek500 containing more firms and industries. This study uses the InformationWeek 500 as it has more recent data, from 1991 to 1997 and has been used by prominent researchers in recent years [53], [52] [54]. For example, papers published from 2008 to 2010 use datasets from the 1980s to the 1990s [27], [53], [52], [54], [28], [6]; including papers in leading IS journals such as IEEE Transactions on Engineering Management [53], Information Systems Research [54], Journal of MIS [52], the Journal of Strategic Information Systems [50], that also used the InformationWeek dataset used in our study. Although InformationWeek stopped publishing individual firm data in 1998, they still continued to publish industry averages, and the industry averages in the periods following 1998 are similar to the 1991-1997 period [27].

Standard & Poor's Compustat database was used to collect firm-level data to measure productivity, industry, and control variables. We matched the firms in the InformationWeek data set to those in the Compustat database both on name and revenue, as InformationWeek verified the company's revenue against public data sources. We left out all firms where we could not get an exact match on revenue between InformationWeek and Compustat, and we also removed all companies where we could not verify any name change through public company history. Summary statistics of our sample are presented in Table 1.

Table 1: Summary Statistics. N = 986

| | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|
| Revenue (in $ millions) | $ 6542.92 | $ 8212.16 | $ 359.03 | $ 137137 |
| IT Budget (in $ millions) | $ 157.83 | $ 214.21 | $ .105 | $ 2087.36 |
| Employees (in thousands) | 33.87 | 45.92 | 1.5 | 486 |
| IPI (Information Product Industries) | | | | |
| Revenue (in $ millions) | $ 5050.05 | $ 5061.99 | $ 626 | $ 31690 |
| IT Budget (in $ millions) | $ 185.08 | $ 212.46 | $ 1 | $ 1280.53 |
| Employees (in thousands) | 19.54 | 23.26 | 2.42 | 202 |
| PPI (Physical Product Industries) | | | | |
| Revenue (in $ millions) | $ 7005.11 | $ 8962.87 | $ 359.03 | $ 137137 |
| IT Budget (in $ millions) | $ 148.57 | $ 214.43 | $ .105 | $ 2087.36 |
| Employees (in thousands) | 38.48 | 50.26 | 1.5 | 486 |

## Variable Operationalization

In operationalizing the variables IT intensity and Firm Productivity for the research model, we need to consider the possibility of reverse causality: Larger firms may have larger revenues and possibly larger profits, and therefore spend more on IT. To control for this reverse causality, there needs to be a strong control for firm size. Operationalizing the variables as a ratio to the number of employees helps to control for these confounding effects. As reported by McAfee and Brynjolfsson [38], corporate investment in IT has surged in recent years, from about $3,500 spent per worker in 1994 to about $8,000 in 2005. In addition, such per employee ratio scales reflect the enabling effect of IT, i.e., IT does not affect firm performance by itself; it provides tools that enable individual employees to achieve better performance by automating and informating their tasks [73]. In his seminal field experiment, Edelman [16] found firms that had implemented an information system were able to handle larger amounts of revenue growth with a much smaller number of employees. Firms that did not implement the information system, on the other hand, were unable to handle the revenue growth and had to go on with a much larger increase in employees. Thus, in this study we operationalize IT Intensity as IT budget divided by the total number of employees, and Productivity as Revenue divided by the number of employees.

The two authors and an independent rater independently classified all the industries in the sample into IPI, PPI, and mixed (i.e., both information and physical products). As this study is focused on the difference between IPI and PPI, we retained only the industries that all three raters had independently classified into PPI or PPI. Industries that were rated as 'mixed' and industries on which there was disagreement between the independent ratings were dropped from the sample. This procedure resulted in 16 PPI and 6 IPI, as in Table 2. Looking at the table, we can easily see that even though the average IS budget may be similar between the two types of industries; the average in budget per employee is generally lower in PPI than in IPI.

Table 2: Physical Product Industries and Information Product Industries in Sample

| SIC Code | Industry | Industry product | N | Average IS Budget (In Millions) | Average IS Budget per Employee |
|---|---|---|---|---|---|
| Sic20 | Food and kindred products | Physical | 47 | $170.24 | $3,052 |
| Sic22 | Textile mill products | Physical | 14 | $31.787 | $1,550 |
| Sic24 | Lumber & wood products | Physical | 13 | $53.238 | $2,085 |
| Sic25 | Furniture and fixtures | Physical | 14 | $73.812 | $2,379 |
| Sic26 | Paper and allied products | Physical | 60 | $96.047 | $2,505 |
| Sic27 | Printing and publishing[1] | Physical | 40 | $53.171 | $3,949 |
| Sic28 | Chemicals and allied products | Physical | 108 | $163.77 | $4,356 |
| Sic29 | Petroleum and coal products | Physical | 35 | 181.51 | $6276 |
| Sic30 | Rubber and miscellaneous plastics products | Physical | 16 | $87.371 | $2,985 |
| Sic32 | Stone, clay, and glass products | Physical | 15 | $125.819 | $3,424 |
| Sic33 | Primary metal industries | Physical | 43 | $43.10 | $2,261 |
| Sic34 | Fabricated metal products | Physical | 26 | $52.542 | $2,086 |
| Sic35 | Industrial machinery and equipment | Physical | 136 | $323.920 | $5,513 |
| Sic36 | Electronic and other electric equipment | Physical | 51 | $189.524 | $4,241 |
| Sic37 | Transportation equipment | Physical | 89 | $276.65 | $3,957 |
| Sic38 | Instruments and related products | Physical | 51 | $159.884 | $3,892 |
| Sic60 | Depository credit institutions | Information | 120 | $210.102 | $10,557 |
| Sic61 | Nondepository credit institutions | Information | 11 | $227.679 | $10,704 |
| Sic62 | Security and commodity brokers, dealers, exchanges, and services | Information | 16 | $329.208 | $14,828 |
| Sic63 | Insurance carriers | Information | 70 | $181.208 | $12,079 |
| Sic64 | Insurance agents, brokers, and services | Information | 6 | $84.163 | $4,578 |
| Sic67 | Holding and other investment offices, except trusts | Information | 5 | $64.229 | $1,723 |

[1] SIC 27: Printing and Publishing - only includes letterpress, lithography (including offset), gravure, or screen, bookbinding and plate-making. It does not include firms that generate the content to be printed

To test Hypothesis 3, we have additional concerns. First, we have to control for the effects of industry and year, since one industry may be more productive than another for reasons internal to the industry and unrelated to IT spending, and firms may be more productive in one year than another. Second, the results may be sensitive to price deflators as IT depreciates at a faster rate than other assets and this differential depreciation can affect the results of this study. To further complicate this issue, although hardware depreciates at faster rate, IT labor may appreciate at a faster rate [22]. In this study, we will attempt to resolve these issues by measuring the independent and dependent variables as relative to their competitors in each two-digit SIC code for each year. Therefore, the variables are operationalized as z scores for firms in each industry for each year.

Brynjolfsson and Hitt [9] also used this measurement approach in their study of IT impact on productivity. The merit and rigor of this approach is essential to our research methodology. Two firms that have the same absolute IT spending per employee may have different z scores if they belong to different industries or different time periods. This z score represents a firm's relative IT intensity compared to peer firms in the same industry who are exposed to the same competitive dynamics. The effects of this relative IT intensity on productivity are determined by each firm's IT efforts compared to peers in the same industry rather than to other firms in other industries. If a firm is making furniture, it may not need to spend as much as Wal-Mart or Bank of America, only more than other competitors in the furniture industry. In addition, on the dependent variable side, productivity can vary. A 5% improvement in productivity may not mean much in banking, but it may mean a lot in furniture. Therefore, with the use of z scores, all firms in the sample are judged on their own merits as compared to their reference group [9].

A time lag of one year was chosen between the independent and dependent variables. One year is typically needed for IT to show some effect on productivity. After an IT system implementation, there is a shakedown period of up to a year before which the benefits start to appear [59]. This first year is needed to uncover and address misfits [19], [66]. According to a study of over 200 companies, it takes over eight months for the benefits to begin to show after ERP implementation [40]. Previous studies (e.g., [68], [72]) have used one-year intervals between variable measurements to afford sufficiently long period of time for the hypothesized causal processes to work out among key variables in the model. A time lag of two years may be too long, as the theorized effects of IT may have dissipated due to other effects that take place in the intervening years.

We have included control variables that may also affect productivity and profit: Capital Expenditures, Research & Development expenses, and Advertisement expenses. These variables have been used in previous studies on IT impacts [5], [7], [22], [27]. All these variables were obtained from the Compustat database and included in our analysis as z-scores relative to other firms in the same industry

## STUDY RESULTS

To test Hypothesis 1, we run ANOVA tests for differences in firm IT intensity between the two types of industries. As results can be sensitive to price deflators [3], we run the tests separately for each year. As we can see from the results in Table 3, for every year, IPI have significantly higher mean Firm IT intensities than PPI. At an average, firms in IPI spend almost 3 times (2.76 times) what their counterparts in PPI spend on IT on each employee. This difference is significant at the $p < 0.001$ level for each of the seven years, lending strong support for Hypothesis 1.

Table 3: Average Firm IT Intensities: Information Product vs. Physical Product Industries

| Year | Mean Firm IT Intensities ($1,000/employee) | | *F-Value* | *F-Critical* | *P* |
|---|---|---|---|---|---|
| | Physical Product Industries | Information Product Industries | | | |
| 1991 | 3.797 | 9.486 | 40.080 | 3.908 | < 0.001 |
| 1992 | 4.155 | 9.854 | 37.944 | 3.919 | < 0.001 |
| 1993 | 4.038 | 11.584 | 44.828 | 3.915 | < 0.001 |
| 1994 | 4.218 | 13.886 | 104.016 | 3.930 | < 0.001 |
| 1995 | 3.306 | 11.214 | 88.261 | 3.888 | < 0.001 |
| 1996 | 4.325 | 9.101 | 40.973 | 3.889 | < 0.001 |
| 1997 | 4.027 | 11.240 | 36.142 | 4.004 | < 0.001 |

To test H2, we computed the variance in Firm IT intensities for each year for both types of industries. As before, due to sensitivity of results to price deflators [3], we run separate tests for each year. The test statistic is the larger variance divided by the smaller variance. As we can see from Table 4, IPI have higher variances in Firm IT Intensities than PPI for every year. For six of the seven years this difference is significant at the 0.001 level. For the remaining year, the difference is significant at the 0.005 level. Therefore, we find strong support for Hypothesis 2. The variance in Firm IT Intensities is over six times (6.216 times) higher among firms in IPI than in PPI.

Table 4: Variance in Firm IT Intensities: Physical vs. Information Product Industries

| Year | Variance: Physical Products (PP) industries | Variance: Information Products (IP) industries | *Variance IP / Variance PP* | *F-Critical* | *p-value* |
|---|---|---|---|---|---|
| 1991 | 7.695 | 60.709 | 7.889 | 2.555 | < 0.001 |
| 1992 | 9.278 | 52.924 | 5.704 | 2.555 | < 0.001 |
| 1993 | 10.206 | 92.632 | 9.076 | 2.555 | < 0.001 |
| 1994 | 12.209 | 28.408 | 2.327 | 2.262 | < 0.005 |
| 1995 | 8.245 | 84.370 | 10.233 | 2.262 | < 0.001 |
| 1996 | 13.233 | 35.144 | 2.656 | 2.262 | < 0.001 |
| 1997 | 6.785 | 38.198 | 5.630 | 4.817 | < 0.001 |

To test Hypothesis 3, we run the PLS Path Models [56] as depicted in Table 5. In this case, due to the z-score operationalizations, annual effects are controlled for, and there is no need to run separate tests for each year as the previous tests. First, we test the base relationship between Relative IT Intensity in time 1 and Relative Productivity in time 2 (Model 1 in Table 5). Here we see that Relative IT Intensity in time 1 has a strong and significant effect on Relative Productivity in time 2 (b = 0.380, p <= 0.001). To test for the moderating effect of IPI on this relationship (Hypothesis 3), we run the following model:

Relative Firm Productivity = β + β1 IT + β2 InfoProduct + β3 IT x InfoProduct + CE + R&D + Ad + e

In this model, IT is the relative Firm IT Intensity and InfoProduct is a dummy variable for the nature of the product of the industry (coded as 1 for IPI and 0 for PPI). CE is Capital Expenditure, R&D is Research & Development Expenses, and Ad is Advertising Expense

Table 5: Testing Hypotheses 3

| | Model 1: Dependent Variable = Relative Productivity | Model 2: Dependent Variable = Relative Productivity |
|---|---|---|
| Constant | 0.00 | 0.00 |
| Industry | 0.00 | 0.00 |
| Year | 0.00 | 0.00 |
| Relative IT Intensity | 0.380*** | 0.277*** |
| Relative IT Intensity x Information Product Industries | | 0.305** |
| Capital Expenditures | 0.355*** | 0.311*** |
| Advertising | 0.118*** | 0.124*** |
| Research & Development | 0.049 | 0.073* |
| Information Product Industries | 0.00 | 0.00 |

*** = p < 0.001; **=p<0.01, *=p<0.05

Here we see that the z-score operationalizations has controlled for the effects of year and industry. In this model, while Relative IT Intensity still has a significant relationship with Relative Productivity, its strength is reduced (b=0.277 in Model 2, as compared to b=0.380 in Model 1). In addition, the difference between the two is also significant, lending strong support for Hypothesis 3. It should be noted that the beta for PPI is β1 in Model 2, i.e., 0.277, while for IPI firms, the beta is β1,+ β3, i.e., 0.277+0.305=0.582. This substantially higher impact of Relative IT Intensity for IPI demonstrates the strong business value of IT for IT innovation leaders in these industries (Figure 2).

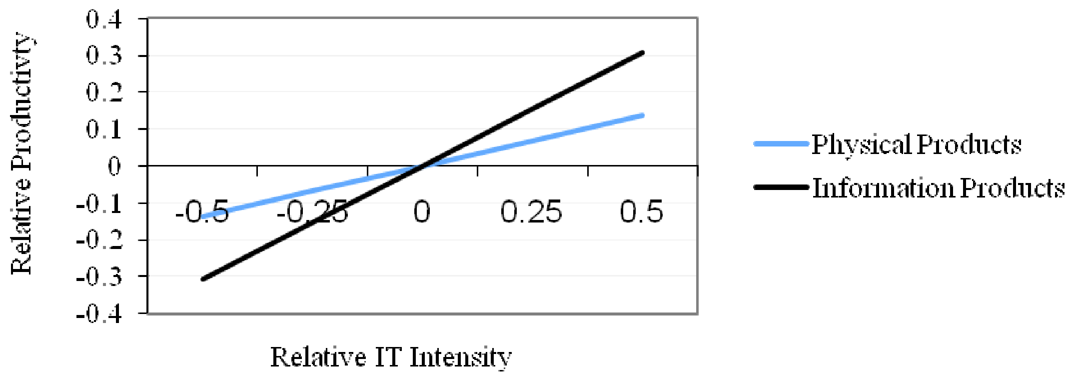


Figure 2: IT – Productivity relationship for Information Product vs. Physical Product firms

## DISCUSSION OF RESULTS

Porter & Millar [48] argued that the IPI-PPI difference may be the most important conceptual difference between industries in regards to their IT effects. This paper tests this postulate through two research questions. The first research question was on the difference in Firm IT Intensities between IPI and PPI firms. In the reasoning for this hypothesis, it was assumed that IPI and PPI have similar IT needs to process information around the product while the IT need to process the product itself was an additional need for IPI. However, the possibility that the IT used by IPI for processing the product may also be used to process information around the product, as well as the possibility that PPI firms may have greater IT needs to process information around the product, may result in lack of support for the hypothesis. However, Hypothesis 1 was strongly supported, and results indicate that firms in PPI spend around $4,000 per employee each year, while those in IPI spend around $11,000 per employee each year, which is nearly 3 times (276%) higher. We might be able to explain this difference in two ways: It may be that the extra amount spent by firms in IPI (i.e., about $7,000 per employee) is on processing the information product itself. Or perhaps these firms may not spend all this extra money on processing the information product, but as they use IT to process the information product, more information is generated that could be used for other value chain activities. Hence, these firms might have more information around the product that represents the extra investment in IT per employee. Future research may need to look into where this extra investment goes.

Hu & Quan's [23] reasoning suggested that IPI have more mature and stable IT than PPI. In contrast to this, Hypothesis 2 suggests that IPI actually have wider variance in their IT than PPI. We find strong support for this hypothesis, as the variance in Firm IT Intensities is six times higher in IPI than in PPI. This implies that firms in PPI may have more similar ideas about how to put IT to use for them. On the other hand, firms in IPI may still be experimenting with their IT investments, with wide ranges in the amount of and perhaps in the variety of IT investments. For example, our data shows that retail banks with over $10 billion in revenue spend between $900 per employee to $48,000 per employee. This indicates that these firms may have vastly different ideas of what to do with IT.

For Hypothesis 3, we find that the relative IT intensity to relative productivity relationship is significantly moderated by industry product type. This means that IT has a lot more to contribute by automating and informating [73] the huge amounts of information processed on a daily basis by the employees in IPI firms, as the productivity effect of relative IT intensity is indeed significantly more positive in these industries than the PPI (see Figure 2). In these firms, IT may provide more variety of, and potentially more creative opportunities for applications that enhance a firm's productivity, than in PPI. Our results on the moderating effects of industry product nature add to our understanding of the different roles of IT is IPI and PPI.

### Profit

Improvements in productivity from IT may not always be retained by firms in the form of profit as the benefits may be competed away or passed on to the consumer in the form of surplus [22]. To test whether IPI firms gain more profit relative to their competitors from increased relative IT intensity as compared to PPI firms, we also run the Hypothesis 3 tests with profit per employee as the dependent variable. The results are similar: firms in IPI have a much stronger relationship between Relative Firm IT Intensity and Relative Firm Profitability than firms in PPI. This difference is significant, indicating that the IT-Profit relationship is also moderated by industry product type.

## CONCLUSIONS

### Limitations

The limitations of secondary data include accuracy, age, context and causality. The first limitation is that the dataset may not be accurate. However, as it is publically available and correlates with other datasets, this is not a primary concern.

A second limitation is that the dataset may not have the most current data. However, it is the most recent publically available dataset and is similar to industry averages of later periods [53], [52]. As a good theory should stand the test of time, data from any time period covered by the theory may be used for the purposes of falsification [55], [69]. For this reason, older datasets are frequently used for testing theory when more recent datasets are not available. For example, IT budget data from the 1990s is used in top IS journals in 2009-2010, for example [53], [52], [54], [50]. However, it should be noted that these results may not be generalizable to time period with exceptional circumstances like the credit bubble and global financial crisis of the 2000-2011 period. In this time period, firms may have done well or poorly for reasons unrelated to IT spending – they may have done well due to the credit bubble of the 2000-2007 and may have done poorly due to the liquidity crisis and the following global financial recession.

A third limitation is that secondary panel data does not give us rich insights into granular details of the specifics of the IT spending. However, as research grows by triangulation, case studies, surveys and field experiments may glean this data in the future.

A fourth limitation is that secondary data does not allow us to establish causality. This study has some control for reverse causality (i.e., larger firms may have more revenues and profits, and therefore may invest more in IT) by operationalizing the variables as per-employee scales to take that factor into account. However, causality is best confirmed through an experimental setting, such as a field experiment (for example, see [16]). Future research can look at such field experiments to establish causality.

### Implications for Practice

Our findings have important implications for practice. One possible factor behind these findings may be that while firms in PPI might have similar investments in IT, firms in IPI may have vastly different ideas of what to do with IT. Further, we have shown that if a firm spends more on IT per employee relative to its competitors in the same industry, it can expect to achieve better performance than these competitors. Since this prospect is more pronounced for information-product firms than physical-product firms, our findings may suggest that IT leaders in IPI may not only have more latitude in exercising innovation and creativity in IT applications, but also that these proactive endeavors can more readily lead to enhanced productivity and market performance. For firms in IPI, the first and foremost strategic priority should be placed on using IT to improve the production process which enables employees to process more information and in more creative ways.

However, this does not mean that IT leaders in PPI firms should be less proactive in leveraging the power of IT. Our findings (Figure 1) indicates that for an average industry, if a firm allocates more IT resource per employee than its competitors in the same industry, the firm is likely to achieve more productivity than these competitors. This gives firms a strong incentive to invest more in IT to outdo their competitors, and is reflected in the increase in IT spending by firms [12], [38]. Both IPI firms and PPI firms can gain productivity improvements through IT by injecting information into their value chains [48]. For physical product firms to gain productivity improvements from IT, they will need to use IT to discover which parts of their physical process are the most inefficient, and then use IT to speed up those aspects. For example, they can identify inefficiencies in purchasing or outbound logistics and use IT for automating or reengineering these processes to make them more efficient. As the manufacturing sector outsources and offshores more and more of its production and even R&D activities, the opportunities for deploying IT to enhance the performance and productivity of the “production chain” proliferates, often with transformational effects [31]. Such recent developments reinforce Porter & Millar's advice for gaining strategic advantage by injecting information into physical processes [48].

## Contribution to Research and Future Directions

Melville et al. point out the need for contingency factors in studying the IT-productivity relationship, and their detailed literature review finds that there is little empirical research on industry differences, and even less on the conceptual reasons why these differences exist [39]. The distinction between information product and physical products is, both practically and conceptually, a very important contingent factor to this relationship, as IT is needed to process information, and industries in which information processing is the main task should be very different in their IT needs and benefits.

In this paper, we build on Porter & Millar's postulate that the PPI-IPI difference is the most important conceptual difference between the IT needs and effects of industries [48] to examine this contingency. Our result from testing Hypothesis 1 lends credence to the notion that the role of modern IT in IPI, as the technology for production of its outputs, is the equivalent of engine and machine tools for the PPI. This provides a basis for examining the role of IT in these two types of industries, since higher IT intensity can be expected to afford a firm more opportunities to deploy IT to improve its productivity and performance.

As IT can be expected to enhance an organization's information processing capacity [18], studying IPI, in which the main purpose is information processing, can help us to gain further insight on the role of IT in a firm and on the complexity of IT impacts. From our empirical tests, we find that firms in IPI spend, at an average, nearly 3 times (276%) of the average firm in a physical product industry. This might mean that the extra 176% is spent on processing the information product. It could also mean that since the firms use IT to process their information products, synergies could be generated allowing for increased information around the product. In addition, for information product firms, one may wonder if there are strategic differences between firms that focus more on investing in IT for processing their products, and those that focus more on processing information around their products. Should investment in one precede the other? How do the benefits obtained vary? Future inquiries into these possibilities should deepen our understanding on the role of IT and its impact in a firm.

Our study results support Hypothesis 2, and reveal that firms in IPI have six times the variance of PPI. This may indicate that the IT investments in PPI firms are relatively similar, while those in IPI are relatively different, in contrast to Hu & Quan's reasoning that the financial sector, which produces information products, has extracted all they can from IT and are now very mature and stable in their IT applications [23]. In information-product industries, is the potential synergy between product and process information processing discussed earlier, responsible for this higher variance? In such industries, since IT is the "engine and machine tools" for the industry's production, one may expect more pressure to apply the rapidly advancing IT to improve the basic production efficiency in order to gain cost and other strategic advantages. Further in-depth case studies and empirical surveys may be conducted to explore these possibilities and improve our understanding of the differentiated role of IT in the two sectors.

The strong support we found for H3 indicates that IT use in IPI appears to have higher payoff. Interestingly, results for H1 and H2 may help to explain this finding. First, the higher IT intensity in the IPI (H1) is most likely a manifestation of the industries' reliance on IT as the "engine and machine tools" for its production process. Since the capability of this production technology has been rapidly advancing, its application in these industries would lead to vast improvement in the efficiency of the production of information products, and thus higher productivity improvement, in comparison to the more mature and stable mechanical/industrial age production technology for the PPI. Higher variance in IT intensity in IPI (H2) and its possible causes may also help to explain H3 results. The greater latitude or flexibility of IT application, as well as the potential synergy between product and process information in IPI, may be the reason why IT use in these industries is more potent in raising productivity. At Allstate Insurance, for example:

"The services-oriented architecture (SOA) makes it much easier to create and alter business processes as needed. That's allowing Allstate, for example, to more easily refine its workflows so that more types of tasks can be handled by claims processors and don't land on the desks of more highly paid adjusters, creating unnecessary labor costs and slowing down the process. SOA also means being able to create a new service, such as one that determines the best path to immediate settlement for a specific type claim, that can be reused for other types of claims" [71].

Our preliminary findings suggest potential differences in how IT is utilized and exerts its effect on productivity across the two types of industries. The door is now open for future research to explore and confirm these and other causes for our findings. In so doing, researchers would have opportunities to theorize and examine the mechanisms through which IT is utilized and exerts its effect on productivity in any industry, not just IPI and PPI.

Future research can also go into more granular detail on how IT affects various aspects of processing of information products in IPI as well as value chain processes across industries. For example, IT could be used for processing credit scores or insurance claims. In IPI firms, such as a credit score company or an insurance firm, these would be primary operations. However, these operations may also be done by PPI firms, as secondary, value-added processes, in which case they may be considered back-office processing. Future research can compare the difference between automating such similar processes in IPI and PPI.

In addition, both IPI and PPI can use IT to sell as well as customize their products. In the case of selling, IT can be used for online ordering of both information and physical products online. However, in the case of IPI, the information product can be purchased and delivered online, while in PPI, the physical product can be ordered online, but has to be shipped offline. Future research can look at the differences between IPI and PPI in just the online ordering and delivery aspect.

In the case of customizing products, in IPI, insurance products or retirement products can be customized for each customer using IT. In PPI, customized computers, clothing, shoes, and cars can be offered to customers through IT as well. In both IPI and PPI, IT can be used to make recommendations can be made based on past purchases. Future research can look for differences between IPI and PPI exist in this case as well. In these cases, the effects may primarily affect individual customer loyalty rather than firm-level productivity or profit.

In this study, we examined the differences between information product firms and physical product firms, but several industries use information to move physical products that they do not make, for example, transportation, shipping, logistics, retail, wholesale, etc. Future studies can look at the differences between these industries, IPI and PPI.

In addition to the research contribution discussed above, we have made very important contributions by improving upon the methodology of earlier studies. We base our operationalizations of the independent variable and dependent variables based on the IT-empowerment perspective [49], [57], which holds that people are the central drivers and the most important components of information systems. Further, by operationalizing the independent and dependent variables as z scores of their particular industry and year, each firm can be measured relative to its competition, removing the sensitivity to price deflators as well as addressing the assumption of similarity of IT investment across industries and years. In addition, the time lags incorporated between the independent and dependent variables provide sufficient time for the hypothesized effects to occur, further improving our ability to discern this relationship.

As research grows through triangulation, the limitation of secondary data can be supplemented by other studies that use other methods of analysis. Case studies, surveys, and field experiments may be able to give us additional insight into the effects of specific type of IT implemented in organizations. In particular, researchers can gather data on the specific type of IT used, for example, business intelligence, ERP, CRM, business performance management, and knowledge management, and study how these impact an organization’s productivity.

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