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The relationship between information technology capability and firm performance in the age of big data analytics with empirical evidence from US companies

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The Relationship between Information Technology Capability and Firm Performance in The Age of Big Data Analytics with Empirical Evidence from US Companies

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ABSTRACT: The purpose of this study is to investigate the relationship between information technology (IT) capability and firm performance in the age of big data analytics (BDA) in the 2010s within a context of US companies. After categorizing firms into pairs of IT leaders and control groups, Wilcoxon signed-rank test and regression analysis are employed to examine how the firm performance of IT leaders and control groups have changed during 2010 to 2017. This research finds that no significant relationship between IT capability and firm performance exists in the age of BDA for US companies. This study will be beneficial to academics and practitioners in further understanding how the adoption and application of BDA derived from IT capability has and will affect the firm performance.

Keywords: *Big Data Analytics (BDA), Information Technology (IT) capability, firm performance, IW 500, IT business value*

Data Availability: *The data are publicly available from the sources identified in the paper.*

I. INTRODUCTION

Understanding of how a firm's Information Technology (IT) capability affects the firm's business performance has been controversial since the 1990s, during which a wealth of literature regarding IT value for business has been developed (Chan 2000; Dehning and Richardson 2002; Kohli and Devaraj 2003; Mahmood and Mann 2000; Melville et al. 2004; Wade and Hulland 2004). In spite of the fact that there are some doubts on IT's direct influence on firm performance (Carr 2003; Clemons 1986, 1991; Clemons and Row 1991; Powell and Dent-Micallef 1997), many IS researchers agree that an excellent performance in IT capability is able to provide the firm with huge competitive advantage over competitors (Chae et al, 2014). However, how IT capability interacts with a firm's performance is more of a mixed relationship (Mata et al. 1995; Ray et al. 2005). Generally, it's acknowledged by the Information Systems (IS) community that firm performance will not be simply improved by IT capabilities per se, though a good IT capability can serve as catalyzer to enable higher-order organizational capabilities and improve firm performance (Ales et al. 2016).

From the 1990s to 2000s, the 1990s is more characterized by proprietary information systems and the 2000s are mainly governed by standardized and identical information systems thanks to the quick adoption of ERP and web technologies (Wang 2010). Accordingly, there exist some studies that investigated the relationship between IT capability and organization performance during different time periods. Among them, the study conducted by Bharadwaj in 2000 that has been cited 5141 times according to data from Google Scholar is one of the most convincing research that gives strong evidence for the link between IT capability and firm performance. This study claimed that IT leaders – those with superior IT capability performed better in business than their counterparts during 1991 to 1994. From the resource-based view (RBV), it argues that firms categorized as IT leaders can make use of IT related resources to

produce a unique IT capability that later become the basis of competitive advantage which creates superior business performance. Santhanam and Hartono did a follow-up study in 2003 that extended the Bharadwaj's research and reassured that the IT leaders show superior performance than that of the control group (the groups that cope with the IT leader firms in terms of industry and size). What's more, this study also found out that the competitive advantage generated through IT capability can be maintained for a period of time. After a widespread change in IT and the way that organizations leverage IT, another study (Chae et al. 2014) updated the above studies with fresh data from the early 2000s. Contrary to the previous findings, this study failed to find that IT leaders were linked with superior business performance, which was measured by profit and cost ratios, no matter it was assessed by the industry-benchmark test, pair-wise comparison test or regression analysis. Moreover, no evidence supported the sustainability of IT capability.

The information technology (IT) business value literature has stressed the potential and abilities of information system to assist in decision-making process and enhance company performance for a long time (Davern and Kauffman 2000; Mithas et al. 2011; Melville et al. 2004; Bhattacharya et al. 2010). The IS's capacity to aid in timely decisions and generate insights that elevate a firm's comparative advantage and act as a tool to deal with environmental uncertainties has been acknowledged in firm performance research (Popovič et al. 2014). As a result, firms depend on the IS to obtain the high-quality information that are possessed with relevance, reliability, accuracy and timeliness (Popovič et al. 2012; Wixom and Todd 2005) thus improving decision making quality and in turn boosting company performance (Mithas et al. 2011). To make use of the advantages of insightful information, accordingly firms are increasingly investing in a variety of technologies and incorporating them into corresponding business activities and processes (Chen et al. 2012).

However, over the past years, with the development of business intelligence and analytics and the related field of big data analytics (BDA), there is a growing trend that both business and academic communities attach more and more importance in the BDA topic (Chen et al. 2012). From the academic community's perspective, BDA related research has grabbed attention from a wide range of scientific outlets, for example *Science* and *Proceedings of the National Academy of Sciences*, due to the nature and significance of BDA (Agarwal and Dhar 2014). Moreover, firms are constantly attempting to generate insights from the expanding volume, velocity, variety, value and veracity of data to make better utilization of data and support decision making (Lavalle et al. 2011; White, 2012). Apart from interpreting data to solve known issues, firms are concentrating on uncovering trends that they failed to notice before (Fosso Wamba et al. 2015). Consequently, the tremendous opportunities along with data, information and analysis in various organization have arouse huge interests in BDA, which is commonly noted as the technologies, systems, techniques, methodologies, practices and applications that analyze various critical business data to enable a firm better assess its market and business, and make effective and efficient business decisions (Gandomi and Haider 2015; Mcafee and Brynjolfsson 2012). Because data source of the BDA mainly comes from a firm's IT-based resources that include physical IT infrastructure, human IT resources, and intangible resources (Agrawal, 2013; Grant, 1991), and IT capability is largely defined as the firm's capability to mobilize, deploy and use IT-based resources to enhance firm's business performance (Santhanam and Hartono 2003), thus IT-based capability plays a significant positive role in the BDA adoption and application. Also, starts from 2010, the academic publications that focus on BDA increased exponentially and the key topic is big data-enabled business value, that is, to store, compute, analyze, visualize and integrate the growing number of data from various sources and transform them into business insights and value. (McAfee and Brynjolfsson, 2012; Wamba et al. 2015). Therefore, this study intends to investigate the

link between a firm's IT capability and business performance in the age of BDA (the 2010s) from US companies.

The hypotheses mainly state that IT leaders are associated with superior business performance and sustained superior business performance compared with the control groups, both before and after the adjustment of the impacts from prior years' financial performance to next year. Based on a sample of 55 sets of IT leaders and control groups selected from the IW 500 and their financial data from 2010 to 2017, this research finds that while IT leaders showed and sustained higher profit ratios than control groups before the financial halo effects adjustment, such linkage no longer existed after the adjustment.

The contribution of this research to the business value of IT literature are twofold. First, this study attempted to dispute or confirm the relationship between a firm's IT capability and business performance by adding a new construct, the influence from BDA since the 2010s. The adoption of BDA-supported decision making enables decision makers to utilize data with improved richness and readiness to enhance the efficiency and effectiveness in making business decisions and thus better business performance. Second, this research renewed the studies with fresh data from the 2010s. The previous studies that investigated the similar topic, i.e., relationship between a firm's IT capability and business performance, were carried out with data from early 1990s and 2000s, and it is questionable that if those conclusions still keep true after a decade of rapid changes in the business use of technologies, especially the prevailed application of big data analytics. Replications and updates play a vital role in the scientific community because they examine the robustness of theories and fortified experimental beliefs into agreed knowledge (Santhanam and Hartono 2003). However, the research community often does not make full use of the replicative studies to reexamine what has been scientifically explored (Berthon et al. 2002).

The remainder of this paper is organized as follows. In the next section, relevant literature is reviewed, and corresponding hypotheses are proposed. In section 3, the research approach, data sources and data analysis procedures are outlined. In section 4, the main findings of this research are presented. In section 5, some possible explanations and unavoidable limitations are explained. In section 6, the synthesis for whole study and some avenues for future research are offered.

II. BACKGROUND AND HYPOTHESIS DEVELOPMENT

IT capability and firm performance

IT capability is largely defined as the firm's capability to mobilize, deploy and use IT-based resources to enhance firm's business performance (Santhanam and Hartono 2003). According to Porter in 2011, firms can elevate their business performance by utilizing their IT capability to reduce costs, increase revenues or both of them. First and foremost, firms with high IT capability is able to increase product differentiation through leveraging web technologies to generate higher sales (Hitt and Brynjolfsson 1996). For example, some banks have launched financial services that rely on websites to differentiate their products and services based on customers' profiles. Also, firms with superior IT capability can improve their sales performance by generating valuable resources such as patents and other intellectual property (Fahy and Hooley 2002). Secondly, superior IT capability plays a vital role in reducing marketing costs by increasing switching costs and customer loyalty (Davenport, 2006). Furthermore, superior IT capability enables a firm to have exclusive access to customer information and their personal preferences, which potentially save future business's research costs (Straub and Watson 2001). This proprietary information will become an insightful resource when firms expands their business into new markets and avoid a heavy toll.

As has been discussed, IT-based resources are categorized into three classifications by Grant in 1991, which are tangible resource consisting of the physical IT infrastructure elements;

the human IT resources consisting of the managerial and technical IT skills and the intangible IT-enabled resources, for example knowledge assets, customer orientation, and synergy.

In resource-based theory, firms are able to integrate innovations more swiftly and improve products by utilizing tangible resources (Bharadwaj, 2000). Compared with a disaggregated and less developed IT infrastructure, a more intenerated IT infrastructure is able to offer a platform for launching innovative IT applications quicker than the competitors (Bharadwaj, 2000). As a result, tangible resources play a role in affecting BDA adoption process.

Human resources comprise two elements, the technical IT skills and managerial skills. Because huge changes of business processes and IT infrastructure will be entailed during BDA adoption process, the coordination between different activities along with process redesign requires a significant input from managerial capability (Zhu et al. 2006).

Intangible resource consists of customer orientation, knowledge assets and synergy (Bharadwaj, 2000). Prior studies indicate that customer orientation also plays a significant part in innovation adoption (Agrawal, 2013). Knowledge assets are defined as how employees' knowledge, skills and experiences in an organization integrated in organization's processes, policies and information repositories (Bharadwaj, 2000). Knowledge assets also play a critical part in the BDA adoption, because if employees' knowledge and skills are well equipped, employees will be more likely to assimilate new innovations. Synergy is referred to as the organization divisional wide sharing of resources and capabilities (Bharadwaj, 2000). Firms that are able to share information and knowledge across different functions and business units are more agile and can respond quicker to address needs. Because BDA technology is empowered to share information across all kinds of key functions such as R&D, purchasing, production, warehouse or marketing, it paves a wonderful path to share information and resources (Agrawal, 2013). Therefore, synergy from intangible resources should also have a positive relationship with BDA adoption and application. Based on the discussion mentioned above, BDA adoption should be significantly positive related to physical IT infrastructure, human IT resources and intangible resources, which demonstrates IT capability.

The above discussion is just a small proportion of how IT capability influences a firm's business performance in the age of age of internet and BDA. Therefore, the following two hypotheses are formulated:

H1: The firms that have superior IT capability in the 2010s are associated with higher average profit ratios than all control firms' average profit ratios.

H2: The firms that have superior IT capability in the 2010s are associated with lower average cost ratios than all control firms' average cost ratios.

Sustainability of IT Capability and Business Performance

Whether the successful business performance developed from IT capability could be sustained in long run has been more and more difficult and significant to answer. On the one hand, unlike the early stages of IT development that are characterized by proprietary information systems, the modern IT environment mainly consists of highly standardized IS applications due to the quick adoption of web technology and ERP, which makes it more simple for a firm to counter and even surpasses its' competitors' IT capability. The time and cost to develop IS are also significantly dropped thanks to other advancements such as off shoring, readily available web search engines and outsourcing (Porter 2001). All of the IT-based competitive advantages obtained from developments mentioned above are short-lived, however (Carr 2003).

On the other hand, since an increasing amount of sensor-generated, mobile and web-based data obtained from IS is constantly producing at large scale, a wealthy amount of relevant, contextualized and detailed contents will be available for firms to generate interesting insights

to guide both short-term and long-term development (Agarwal and Dhar 2014; Chen et al. 2012). Those IT-enabled intangible assets, for instance knowledge assets are likely to enhance technology competence and capabilities, thus resulting in an influence on firm performance and IT projects. (Barney 1991; Bharadwaj 2000; Mata et al. 1995; Melville et al. 2004; Santhanam and Hartono 2003; Wade and Hulland 2004).

Despite the changing IT environment where firms can obtain applications and analytical insights easier than before (Chae et al, 2014), a firm's IT capability is likely to be linked to sustainable business performance, so the following two hypotheses are formulated:

H3: The firms that have superior IT capability in the 2010s are associated with higher average profit ratios than all control firms' average profit ratios in all subsequent years.

H4: The firms that have superior IT capability in the 2010s are associated with lower average cost ratios than all control firms' average cost ratios in all subsequent years.

Financial Halo Effect

According to previous studies, it's found that the results of popular industry rankings, for instance *Fortune*'s Most Admired Companies can be affected by prior financial performance to a large extent, and the influence of prior financial performance on a reputation survey is defined as a financial halo effect (Brown and Perry 1994). In prior study (Bharadwaj 2000), the researcher performed a test to ensure that the selection as an IT leader comes from firm's IT capability rather than the previous financial performance, and she didn't find the existence of financial halo effect. It is of great importance to ensure that a firm is recognized as an IT leader according to its superior IT capability, not because of its previous financial performance (Chae et al, 2014). Otherwise, the reliability and validity for the comparisons of business performance between the IT leaders and control groups can be doubted.

In the follow up study (Santhanam and Hartono, 2003), Santhanam and Hartono also further investigated the issue of financial halo effect. They argued that in Bharadwaj's study, the test of a financial halo effect on selection of IT leaders might not be sufficient enough since Bharadwaj used the previous five years' financial performance in spite of the fact that the ranking is affected most by a firm's immediate past performance. Therefore, they claimed that the influence of IT capability should be reexamined via a more conservative and rigorous method by adjusting the past financial performance. In their study, their concerns were proved legitimate because the largely better performance of IT leaders over the control samples presented in the pair-wise comparison test turned significantly weak when the previous financial performance were adjusted in the test.

In line with Santhanam and Hartono's methodology, another study (Chae et al, 2014) also examined this issue to make sure that IT capability is the one element that causes the differences between the IT leaders and control companies rather than past financial performance. As the researchers expected, the previous year's performance has a huge impact on the current year's performance, which are consistent with Santhanam and Hartono's outputs. Same with Santhanam and Hartono's approach, this study also wants to ascertain that IT capability is the one element that differentiates between the IT leaders and control companies, not previous performance. As a consequence, additional tests in controlling the effects of previous financial performance on results should be performed, and thus the following hypotheses are proposed in this study:

H5: The firms that have superior IT capability in the 2010s are associated with higher average profit ratios than all control firms' average profit ratios after adjustment of prior financial performance.

H6: The firms that have superior IT capability in the 2010s are associated with lower average cost ratios than all control firms' average cost ratios after adjustment of prior financial performance.

H7: After adjustment of prior financial performance, the firms that have superior IT capability in the 2010s are associated with higher average profit ratios than all control firms' average profit ratios in subsequent years.

H8: After adjustment of prior financial performance, the firms that have superior IT capability in the 2010s are associated with lower average cost ratios than all control firms' average cost ratios in subsequent years.

Also, since this study is conducted after Bharadwaj in 2000, Santhanam and Hartono in 2003 and Chae's group in 2014 and their research methodologies are heavily referenced, a comparison between those studies are presented in Table 1.

TABEL 1
Comparisons Between Earlier Studies and Current Study

Studies	Sample	Benchmark (Control Group)	Measures
Bharadwaj (2000)	IT leaders from 1991–1994 IW 500 listings	IT leader versus control company of similar size and industry	Business performance measured by profit and cost ratios from 1991 to 1994
Santhanam and Hartono (2003)	IT leaders from 1991–1994 IW 500 listings	IT leaders versus industry average	1. Business performance measured by profit and cost ratios from 1991 to 1994 2. Sustainability of superior business performance from 1995 to 1997
Chae et al (2014)	IT leaders selected from 2001–2004 IW 500	IT leaders versus control companies of similar size and industry	1. Business performance measured by profit and cost ratios from 2001 to 2004 2. Sustainability of superior business performance from 2005 to 2007
This study	IT leaders selected from 2010–2013 IW 500	IT leaders versus control companies of similar size and industry	1. Business performance measured by profit and cost ratios from 2010 to 2013 2. Sustainability of superior business performance from 2014 to 2016

III. RESEARCH METHOD AND EMPIRICAL RESULTS

Bharadwaj's "matched sample comparison group" is used in this research to test the formulated hypotheses empirically. This technique includes the selection of a treatment sample and a control sample, and then compares the interest variables' levels between these two groups. In this study, the treatment sample consists of the IT leaders with superior IT capability, and the control sample consists of the firms that are match to the control sample according to similar industry and size. After the above steps, the performance measurement results of IT leaders will be compared with those of the control groups.

Data Source and Sample Selection: IT Leaders and Control Firms

In the IS community, IS researchers have devoted to identifying IT leaders that are possessed with superior IT capability, and *Information Week* 500 have been used for the identification for many years. Ever since 1989, *Information Week* (IW) has selected and recognized 500 companies as annual leaders in business technology innovation. Since IW 500 list's first publication, the criteria in choosing IT leaders have been evolving to better reflect ever-changing business and technology advancements and to sophisticatedly modify its benchmarking power. In spite of the frequent changes in selection criteria, IW 500 is still

recognized as a reliable indicator for firm's IT capability and has been applied in previous academic research (Bharadwaj 2000; Hitt and Brynjolfsson 1996; Chae et al, 2014; Santhanam and Hartono 2003; Stoel and Muhanna 2009).

The firms with superior IT capability are those recognized in IW 500 from 2010 to 2013. To select the firms with sustainable IT capability, the IT leader sample was limited to firms that were listed in IW 500 for at least two years during the four years.

The matching control firms were selected based on sales levels – those who have the closest five-year average sales level with the IT leaders will be chosen. As Bharadwaj claimed, the control firms' average sales level should be in the 70 to 130 percent scope of those of the leader firm. In short, the control company is supposed to be in the same industry as the IT leader, and its average sales from 2005 to 2009 should be between 70 percent and 130 percent of the leader's average sales during the same period. Table 2 summarizes the sample selection step by step.

TABEL 2
Sample Selection Methods

Step	Procedure	Number of Companies
1	Identify companies listed in the IW 500 from 2010 to 2013	2,000
2	Restrict the IT leader sample to those that were listed at least twice in the IW 500 from 2010 to 2013	569
3	Select IT leaders with comparable companies	276

It is critical to choose the control firm in the same industry and similar size for the following reasons. First, operating performance ranges from each other widely due to different industries and firm sizes. Therefore, the difference in performance caused by the variance in industry and firm size can be significantly reduced after using the matching samples (Chae et al, 2014). What's more, according to accounting literature, industry type and firm size can be strong predictors for the accounting methods and process to calculate costs, for example the amortization and depreciation (Bharadwaj 2000). As a result, the effects of variance from accounting methods can be effectively controlled, which allows for more reliable comparison between profitability and cost ratios.

This study also only selected a single control firm (benchmark) for each IT leader firm and didn't take all other firms in that industry into account for comparison (Chae et al, 2014).

As Table 3 indicates, firms categorized as IT leaders are in quite large size, with total assets about 24.4 billion and average sales of 7.5 billion. This research showed that IT leaders are almost twice larger than the average size of all other firms in their corresponding industries. As has been discussed earlier, the firm size will directly influence firm's IT budgets and resources, and it's possible that IT leaders have more IT resources than other firms in the industry.

TABEL 3
Comparison Between the IT Leader Group and the Control Group

Descriptive Variables	IT Leader Sample		Control Sample	
	Mean	Median	Mean	Median
Sales (billion $)	7.512	1.489	4.315	1.943
Assets (billion $)	24.398	2.145	12.826	2.596
Number of Employees (thousand)	20.173	5.364	16.252	6.386

The measurements chosen to reflect business performance in this study were the same with the variables in Bharadwaj's study. Superior business performance is defined by profit and cost performance, which are higher profit ratios and lower cost ratios. More specifically, the profit ratios category includes the following: (1) return on assets (ROA), (2) return on sales (ROS), (3) operating income to assets (OI/A), (4) operating income to sales (OI/S), and (5) operating income to employees (OI/E). Since Bharadwaj's study didn't clearly define operating income, earnings before interest payment and taxes (EBIT) will be used as the operating income in this study. The cost ratios category includes the following: (1) total operating expenses to sales (OPEXP/S), (2) cost of goods sold to sales (COG/S), and (3) selling and general administrative expenses to sales (SGA/S). Operating expenses are computed as the sum of SGA and COG as the same with Bharadwaj's study.

Bloomberg database was the source of financial data. The data was aimed to find out whether IT leaders have lower cost and higher profit than their corresponding control companies during the same time period between 2010 and 2013.

The sustainability of superior business performance is assessed by whether IT leaders hold higher profit and lower cost over time. Both IT leaders' and control firms' profit and cost ratios were analyzed over the period from 2014 to 2017. The constructs and corresponding measurement used in this research are summarized in Table 4.

TABLE 4
Summary of Constructs and Measurement

Category	Constructs	Definition	Measurement	Sources
Independent variable	IT Capability	A firm's ability to assemble, integrate and deploy IT-based resources.	The firms ranked Information Week 500 more than twice from 2010 to 2013	Bharadwaj (2000); Rai et al. (1997)
Dependent variables	Superior Business Performance	Higher profit and lower cost than the control group.	ROA, ROS, OI/A, OI/S, OI/E, COG/S, SGA/S, OPEXP/S from 2010 to 2013	Bharadwaj (2000); Porter (1985)
	Sustained Superior Business Performance	Sustained higher profit and lower cost than the control group.	ROA, ROS, OI/A, OI/S, OI/E, COG/S, SGA/S, OPEXP/S from 2014 to 2017	Bharadwaj (2000); Santhanam and Hartono (2003)

However, after extracting all IT leaders and control groups' financial data from Bloomberg, only 56 sets of IT leaders and control groups remained valid for research because of the following reasons. On the one hand, not all the companies selected by IW 500 are listed companies. Therefore, the financial data of unlisted companies could not be found from Bloomberg and thus could not further support the research. 13 sets of groups were eliminated due to this reason. On the other hand, because this study requires consecutive data from 2010 to 2017, any variable missing in any of the year will make this group invalid. Most missing values come from the employee numbers and selling and general administrative expenses. As a result, only 56 sets of groups that contained IT leaders and control groups were kept.

Statistical Tests

This research investigates whether firms with higher IT capability are likely to show superior financial performance compared with the matching control firms. Comparing the mean value of variables for the IT leader group and the control sample via a standard t-test is

one of the methods to test the hypotheses. Nevertheless, because the sample is not normally distributed, the Wilcoxon signed-rank test, a non-parametric test was applied. This test classifies one IT leader firm and corresponding control firm into one pare, and the differences between the pairs will be measured. By adopting the Wilcoxon signed-rank test, the variance in performance caused by the difference in industry can be effectively removed (Chae et al, 2014).

Consistent with Santhanam and Hartono's study, the same regression analysis methods for testing hypotheses 5, 6, 7, and 8 are adopted. Each financial performance measurement was conducted by two separate regression analysis as follows. For the first analysis, it investigates into how previous performance affects current year's performance, so a regression analysis that regresses previous years' performance on current performance was performed. For the second analysis, an additional binary variable was used to distinguish IT leaders from control firms (1 for IT leaders, and 0 for the control group). The two models can be expressed as follows

$$FP_t = \beta_0 + \beta_1 FP_{(t-1)}$$

$$FP_t = \alpha_0 + \alpha_1 FP_{(t-1)} + \alpha_2 D$$

Where FP stands for financial performance, t denotes the time period, D means the (0,1) binary variable, α_1, α_2 and β_1 are regression coefficient, and β_0 and α_0 indicate the intercepts. It is α_2, the significance of the coefficient of the dummy variable in the second model that decides whether the IT capability has a significant influence on business performance after the adjustment for the effects of previous financial performance on current performance.

Empirical Results for Superior Business Performance and Sustained Superior Business Performance

The statistical results of the Wilcoxon signed-rank test from 2010 to 2017 are presented in Table 5 and Table 6. Both the mean and median of the performance measurement are displayed. The statistical test results are reported as P values and Z values.

The first hypothesis, that IT leaders have higher profit ratios than control groups, was supported. The IT leader group were associated with better performance in terms of profit ratios including ROA, ROS, OI/A, and OI/E for all four years from 2010 to 2013. Notably, the ROA and ROS showed high significance level from the 2011 to 2013. The second hypothesis regarding cost ratios held partially true. IT leaders' OPEXP/S were higher in three of the four years, COG/S were higher in all four years, and only SGA/S were lower in all four years. The third and fourth hypotheses that examines whether superior business performance driven by IT capability can sustain over time are displayed in Table 6. IT leaders did show higher profit ratios than control firms in all four years from 2014 to 2017, and thus hypothesis three was fully supported. Similar to hypothesis one, the ROA and ROS showed high significance level from the 2014 to 2017. For hypothesis four, IT leaders had higher COG/S than control group in all four years while they deployed lower OPEXP/S and SGA/S in all four years. Consequently, hypothesis 6 was partially supported.

TABEL 5
Results of Test on Superior Business Performance

		2010				2011				2012				2013			
		Mean	**Median**	**Z Value**	**P Value**	**Mean**	**Median**	**Z Value**	**P Value**	**Mean**	**Median**	**Z Value**	**P Value**	**Mean**	**Median**	**Z Value**	**P Value**
ROA	Control Group	-0.135	0.189	-1.315	0.188	0.005	0.206	-2.287	0.022**	0.052	0.204	-2.899	0.004***	0.033	0.214	-2.421	0.015**
	IT Leaders	0.184	0.247			0.381	0.356			0.414	0.371			0.401	0.373		
ROS	Control Group	-0.225	0.216	-1.324	0.186	-0.027	0.211	-2.606	0.009***	0.065	0.211	-2.547	0.011**	0.084	0.258	-2.095	0.036**
	IT Leaders	0.164	0.249			0.481	0.337			0.504	0.368			0.523	0.415		
OI/A	Control Group	0.056	0.069	-1.935	0.053	0.075	0.079	-2.036	0.042**	0.082	0.080	-1.642	0.101	0.063	0.075	-1.935	0.053*
	IT Leaders	0.102	0.086			0.111	0.093			0.112	0.092			0.100	0.099		
OI/S	Control Group	0.055	0.083	-1.567	0.117	0.129	0.107	-1.106	0.269	0.136	0.127	-0.536	0.592	0.133	0.120	-0.302	0.763
	IT Leaders	0.126	0.111			0.158	0.126			0.149	0.126			0.143	0.129		
OI/E	Control Group	-12.189	24.600	-1.357	0.175	55.344	30.686	-1.517	0.129	40.545	35.311	-0.494	0.621	44.309	30.274	-0.469	0.639
	IT Leaders	47.034	26.816			76.507	42.437			62.538	39.956			64.801	35.622		
OPEXP/S	Control Group	0.845	0.856	0.628	0.530	0.802	0.843	0.017	0.987	0.785	0.820	-0.737	0.461	0.797	0.831	-0.829	0.407
	IT Leaders	0.826	0.827			0.804	0.812			0.812	0.840			0.818	0.840		
COG/S	Control Group	0.541	0.530	-0.922	0.357	0.510	0.508	-1.634	0.102	0.497	0.486	-1.935	0.053*	0.493	0.458	-1.927	0.054*
	IT Leaders	0.714	0.546			0.741	0.582			0.755	0.571			0.715	0.567		
SGA/S	Control Group	0.304	0.280	1.366	0.172	0.292	0.283	1.223	0.221	0.288	0.296	1.173	0.241	0.303	0.318	1.081	0.280
	IT Leaders	0.243	0.215			0.237	0.198			0.243	0.199			0.258	0.210		

TABEL 6
Results of Test on Superior Business Performance Sustainability

		2014				2015				2016				2017			
		Mean	**Median**	**Z Value**	**P Value**	**Mean**	**Median**	**Z Value**	**P Value**	**Mean**	**Median**	**Z Value**	**P Value**	**Mean**	**Median**	**Z Value**	**P Value**
ROA	Control Group	-0.079	0.232	-2.086	0.037**	-0.273	0.236	-2.145	0.032**	-0.256	0.203	-2.329	0.020**	0.106	0.199	-2.321	0.020**
	IT Leaders	0.363	0.353			0.348	0.333			0.369	0.384			0.374	0.390		
ROS	Control Group	0.076	0.258	-2.044	0.041**	-0.469	0.229	-2.296	0.022**	-1.308	0.228	-2.220	0.026**	0.212	0.312	-1.659	0.097*
	IT Leaders	0.552	0.392			0.573	0.411			0.613	0.476			0.680	0.472		
OI/A	Control Group	0.053	0.073	-2.338	0.019**	-0.028	0.085	-2.790	0.005***	0.059	0.069	-1.399	0.162	0.074	0.070	-1.173	0.241
	IT Leaders	0.107	0.094			0.111	0.096			0.095	0.091			0.095	0.089		
OI/S	Control Group	0.108	0.122	-0.804	0.421	-0.011	0.108	-2.371	0.018**	0.067	0.101	-1.927	0.054*	0.144	0.112	-0.913	0.361
	IT Leaders	0.164	0.127			0.192	0.148			0.181	0.144			0.178	0.147		
OI/E	Control Group	-24.111	31.750	-1.181	0.238	-17.450	27.258	-2.539	0.011**	14.930	30.048	-2.028	0.043**	51.092	31.487	-1.114	0.265
	IT Leaders	75.757	41.317			79.875	45.451			76.663	41.653			80.022	39.973		
OPEXP/S	Control Group	0.820	0.823	0.151	0.880	0.925	0.842	1.592	0.111	0.865	0.852	1.039	0.299	0.794	0.833	0.553	0.580
	IT Leaders	0.792	0.815			0.767	0.811			0.778	0.813			0.779	0.804		
COG/S	Control Group	0.526	0.492	-1.282	0.200	0.611	0.490	-0.243	0.808	0.493	0.472	-0.679	0.497	0.498	0.474	-0.628	0.530
	IT Leaders	0.703	0.561			0.656	0.439			0.630	0.445			0.607	0.496		
SGA/S	Control Group	0.293	0.294	1.785	0.074*	0.313	0.326	1.617	0.106	0.373	0.315	2.044	0.041**	0.296	0.276	1.349	0.177
	IT Leaders	0.244	0.211			0.248	0.225			0.263	0.239			0.248	0.227		

ROA: return on assets; ROS: return on sales; OI/A: operating income to operating expense to assets; OI/S: operating income to sales; OI/E: operating income to employees; OPEXP/S: operating expense to sales; COG/S: cost of goods sold to sales; SGA/S: selling and general administration expense to sales

Empirical Results for Adjustment of Financial Halo Effects

To understand how IT capability affects business performance after adjustment of previous year's firm performance, regression analysis was conducted. The results are reported in Table 7. Specifically, the regression coefficients of models in equations 1 and 2 and changes in R-squares are presented in the Table 7. Consistent with the study's expectation, the previous year's organizational performance has a significant impact on the current year's organizational performance. However, according to the significance of the coefficient of the dummy variable for profit ratios and cost ratios in the second model, only the ROA in 2011 with a positive coefficient was significant in 5 percent level. Therefore, none of the hypotheses for five to eight were supported. The results of all hypotheses tests are summarized on Table 8.

TABEL 7
Regression Analysis

2011

	Model	R Square Change	2010 Financial Performance	Dummy Variable
ROA	1	0.027	0.130	
	2	0.099	0.088	0.348**
ROS	1	0.054	0.202	
	2	0.120	0.157	0.448
OI/A	1	0.017	0.116	
	2	0.044	0.086	0.033
OI/S	1	0.058	0.137	
	2	0.064	0.130	0.020
OI/E	1	0.008	0.051	
	2	0.013	0.046	18.431
OPEXP/S	1	0.008	0.087	
	2	0.008	0.087	0.003
COG/S	1	0.000	-0.010	
	2	0.048	-0.054	0.240
SGA/S	1	0.004	0.058	
	2	0.027	0.038	-0.053

2012

	Model	R Square Change	2011 Financial Performance	Dummy Variable
ROA	1	0.093	0.284	
	2	0.144	0.220	0.280
ROS	1	0.246	0.476	
	2	0.262	0.438	0.217
OI/A	1	0.002	0.039	
	2	0.027	0.011	0.030
OI/S	1	0.035	0.210	
	2	0.036	0.206	0.007
OI/E	1	0.062	0.253	
	2	0.066	0.248	16.748
OPEXP/S	1	0.011	0.101	
	2	0.019	0.101	0.027
COG/S	1	0.022	-0.146	
	2	0.100	-0.207	0.306

SGA/S	1	0.007	0.081	
	2	0.022	0.062	-0.042

2013

	Model	R Square Change	2012 Financial Performance	Dummy Variable
ROA	1	0.135	0.406	
	2	0.166	0.343	0.243
ROS	1	0.155	0.416	
	2	0.178	0.370	0.276
OI/A	1	0.036	0.246	
	2	0.051	0.219	0.030
OI/S	1	0.001	0.025	
	2	0.002	0.024	0.010
OI/E	1	0.043	0.163	
	2	0.049	0.158	17.018
OPEXP/S	1	0.006	0.092	
	2	0.010	0.086	0.019
COG/S	1	0.042	0.195	
	2	0.071	0.153	0.182
SGA/S	1	0.079	0.290	
	2	0.088	0.277	-0.032

2014

	Model	R Square Change	2013 Financial Performance	Dummy Variable
ROA	1	0.083	0.504	
	2	0.096	0.444	0.278
ROS	1	0.052	0.261	
	2	0.087	0.204	0.387
OI/A	1	0.002	0.055	
	2	0.034	0.021	0.053
OI/S	1	0.015	-0.182	
	2	0.031	-0.188	0.057
OI/E	1	0.000	-0.021	
	2	0.023	-0.068	101.259
OPEXP/S	1	0.001	-0.029	
	2	0.006	-0.024	-0.027
COG/S	1	0.030	0.177	
	2	0.049	0.146	0.144
SGA/S	1	0.079	0.275	
	2	0.091	0.261	-0.037

2015

	Model	R Square Change	2014 Financial Performance	Dummy Variable
ROA	1	0.040	0.291	
	2	0.062	0.248	0.511
ROS	1	0.077	0.750	
	2	0.094	0.662	0.726
OI/A	1	0.003	0.209	
	2	0.018	0.127	0.132
OI/S	1	0.004	0.202	

	2	0.023	0.148	0.195
OI/E	1	0.000	0.050	
	2	0.016	-0.008	260.108
OPEXP/S	1	0.008	0.274	
	2	0.025	0.246	-0.150
COG/S	1	0.007	0.124	
	2	0.008	0.120	0.023
SGA/S	1	0.007	0.088	
	2	0.037	0.061	-0.062

2016

	Model	**R Square Change**	**2015 Financial Performance**	**Dummy Variable**
ROA	1	0.191	0.496	
	2	0.199	0.478	0.328
ROS	1	0.453	1.997	
	2	0.453	2.003	-0.166
OI/A	1	0.064	0.055	
	2	0.079	0.052	0.029
OI/S	1	0.093	0.155	
	2	0.107	0.146	0.084
OI/E	1	0.094	0.046	
	2	0.119	0.043	50.482
OPEXP/S	1	0.062	0.154	
	2	0.070	0.146	-0.064
COG/S	1	0.076	0.187	
	2	0.093	0.184	0.129
SGA/S	1	0.212	1.014	
	2	0.215	0.990	-0.045

2017

	Model	**R Square Change**	**2016 Financial Performance**	**Dummy Variable**
ROA	1	0.039	0.056	
	2	0.087	0.045	0.239
ROS	1	0.012	0.013	
	2	0.067	0.010	0.449
OI/A	1	0.094	0.216	
	2	0.101	0.207	0.013
OI/S	1	0.019	0.056	
	2	0.028	0.050	0.028
OI/E	1	0.010	0.053	
	2	0.033	0.037	26.670
OPEXP/S	1	0.014	0.050	
	2	0.016	0.048	-0.011
COG/S	1	0.049	0.202	
	2	0.057	0.191	0.082
SGA/S	1	0.026	0.071	
	2	0.040	0.063	-0.041

TABEL 8
Summary of Hypotheses Tests

Hypotheses	Results
H1: The firms that have superior IT capability in the 2010s are associated with higher average profit ratios than all control firms' average profit ratios.	Supported
H2: The firms that have superior IT capability in the 2010s are associated with lower average cost ratios than all control firms' average cost ratios.	Partially Supported
H3: The firms that have superior IT capability in the 2010s are associated with higher average profit ratios than all control firms' average profit ratios in all subsequent years.	Supported
H4: The firms that have superior IT capability in the 2010s are associated with lower average cost ratios than all control firms' average cost ratios in all subsequent years.	Partially Supported
H5: The firms that have superior IT capability in the 2010s are associated with higher average profit ratios than all control firms' average profit ratios after adjustment of prior financial performance.	Not Supported
H6: The firms that have superior IT capability in the 2010s are associated with lower average cost ratios than all control firms' average cost ratios after adjustment of prior financial performance.	Not Supported
H7: After adjustment of prior financial performance, the firms that have superior IT capability in the 2010s are associated with higher average profit ratios than all control firms' average profit ratios in subsequent years.	Not Supported
H8: After adjustment of prior financial performance, the firms that have superior IT capability in the 2010s are associated with lower average cost ratios than all control firms' average cost ratios in subsequent years.	Not Supported

IV. DISCCUSIONS

This research tries to answer a vital question: does the relationship between firm's IT capability and business performance still hold true after large technology advancement such as BDA? Both positive link and no positive link between IT capability and organizational performance were found in previous studies (Bharadwaj 2000; Chae et al, 2014; Santhanam and Hartono 2003). Nevertheless, these research used data from the early 1990s and 2000s, so updates on our understanding are necessary. Therefore, this study replicates, extends and updates the three previous studies with the data from the 2010s to investigate how the advantages bring by being an IT leader have changed since the early 1990s. The meaning of this method lies in that IS researchers generally underutilize the replications and updates while replications and updates are important elements of scientific studies (Berthon et al. 2002).

The expected results are that IT leaders from 2010 to 2013 were associated with higher profit ratios and they also sustained such performance during 2014 to 2017. However, IT leaders were not necessarily accompanied by lower cost ratios from 2010 to 2017, which were unexpected. What's more, after the adjustment of financial halo effect, which aimed to remove the effects from the prior year's financial performance to next year, nor superior business performance or sustained superior business performance were associated with the IT leaders.

To analyze the expected and unexpected results, it's necessary to understand the role of IT capability and BDA on business performance since the 2010s. As has been discussed, IT capability plays a significant positive role in the BDA adoption and application. Due to the hypercompetitive nature of modern business environments, nowadays firms' attention has been attracted to utilize IT capability-enabled information to develop organizational capabilities (Chakravarty et al. 2013). The application of BDA plays an important role particularly in

assisting operational and strategic decision making and thus enhancing organizational performance (Kiron et al. 2014). Insights derived from the BDA possess the potential to improve real-time business process monitoring and measurement, enhance the quality control (Waller and Fawcett 2013; Davenport et al. 2012), reinforce customer relationships, manage operational risks, elevate operational efficiency and effectiveness, or to facilitate the product or service delivery (Kiron 2013; Zelbst et al. 2011). Therefore, the results of hypotheses one and three, which showed that the IT leaders were associated with higher profit ratios and such advantages were sustained, could be validated by the above reasons.

However, transforming the advantages brought by IT capability and BDA into business values also faces many challenges. The challenges start from the senior level, where top level decision makers need to embrace evidence-based decision making and lead the whole organization to refine the understanding of judgment (McAfee and Brynjolfsson, 2012). Also, the readiness factors and organizational design are critical factors for IT utilization and thus developing IT capability may not necessarily enhance business performance (Hong and Kim 2002; Dezdar and Sulaiman 2010). To sum up, the capabilities of firms in utilizing BDA (such as data sourcing, access, integration, delivery, the advanced analytics capacity and capabilities, and human resources) and organizational factors (in terms of top management support, BDA strategy, financial resources, and engaging people) can both inhibit or facilitate effective utilization of BDA in operations, and thus the benefits from BDA utilization doesn't translate into business values quickly and easily (Popovič et al. 2014). Therefore, this study speculates that the high costs associated with the BDA adoption and application are also reflected in firm's cost ratios, which explains the results of hypotheses two and four.

The results that none of the hypotheses from five to eight were supported is thought-provoking because the regression conducted in this study is regarded more conservative and rigorous than the pair-wise comparison by adopting the Wilcoxon signed-rank test (Santhanam and Hartono 2003). Despite the fact that the results are surprising, similar patterns were also found in previous studies (Chae et al, 2014; Santhanam and Hartono 2003). These researchers also found that the significant effect of IT capability on organizational performance presented in pair-wise comparison became less apparent when measured with regression analysis.

Reliability & Validity

This paper follows the methodology and instructions from a model paper published in the leading journal of management information system, *MIS Quarterly* (Chae et al, 2014). Although data was extracted from different years, the results of hypotheses tests are similar to the model paper. As has been discussed earlier, the model paper also found that no linkage existed between IT capability and business performance after the adjustment of previous year's firm performance. Therefore, this research is reliable. In terms of validity, the results of this study can only be generalized within US listed firms. First of all, the IW 500 only selects firms from the United States. Also, 13 firms acknowledged as IT leaders by IW 500 were excluded because they were not listed companies, which made their financial data inaccessible and could not be incorporated into this study. Besides, a total of 207 firms' financial data were not fully available in Bloomberg (i.e., missing values in certain years for certain variables), and thus they were not taken into account likewise. The firms eliminated due to the reason above could have made significant difference to this study's results, but it is not feasible to discuss their impacts under current condition.

Limitations

Though our findings indicate that a strong IT capability does not necessarily links firm with superior and sustained business performance in the age of BDA, it is premature to make such a claim. While more research is needed to understand the mechanism of IT capability and

business performance in the age of BDA, following limitations are offered as the rationales to help understand the results critically. To systematically assess the limitations of this research, firstly the sample selection should be investigated. As has been shown in table 3, the average sales and assets of IT leaders' group were almost twice as many as the control group. Therefore, the firm size, different IT budgets or slight accounting maneuvers in depreciation and amortization may affect their net income and thus the financial measurements (Chae et al, 2014). Secondly, potential threats may come from the sample selection process. Although choosing sample from IW 500 has its advantages such as the quality of respondents and a high response rate, IW 500's frequent and inevitable changes in selection process have posed challenges for researchers who pay attention to the benchmarking criteria. In fact, since IW 500 published its first list in 1989, IW 500's selection criteria for inclusion have continuously changed and the process is not consistent (Chae et al, 2014). What's more, the firm selection procedure adopts a binary measure that firms are either identified as leaders or not leaders. Such a measurement method makes the evaluation of the influence of incremental improvements in IT capability on firm performance impossible (Santanam and Hartnono 2003).

Theoretical Contributions

This research adds value to the IT literature from two aspects. Firstly, this study tried to refresh the understanding of how a firm's IT capability relates to its business performance by introducing the impacts from BDA since the 2010s. Secondly, this research renewed the studies with fresh data from the 2010s. The previous research that discussed the similar topic, i.e., the relationship between a firm's IT capability and business performance, were conducted with data from early 1990s and 2000s, and it is doubtful that whether those findings still hold true after a decade of dramatic changes in the business use of technologies, especially the growing popularity and application of adopting big data analytics as part of business strategies.

V. CONCLUSION

Motivated by the growing worldwide attention in, but insufficient evidence of, whether a firm's IT capability relates to its financial performance in the age of BDA, this issue is investigated within the context of US by (1) selecting IT leaders and corresponding control groups from IW 500 and comparing their profit ratios and cost ratios from 2010 to 2017 and (2) adjusting the financial halo effects to remove the effects from prior year's financial performance to next year. The findings of this research indicate that while IT leaders did show and sustain higher profit ratios than control groups before the financial halo effects adjustment, such linkage no longer exists after the adjustment. Since the 2010s, both academic and business communities became more and more interested in big data-enabled business value (McAfee and Brynjolfsson, 2012; Wamba et al. 2015), while the storage, computation, analysis, visualization and integration of big data heavily rely on firm's IT capability.

Therefore, this research serves as a future reference for business and academic communities in considering adopting the BDA strategy as part of IT capability to positively influence business performance. It is also an incremental study after Bharadwaj in 2000, Santhanam and Hartono in 2003 and Chae in 2014 by taking the BDA factor into consideration with the latest data from the 2010 to 2017. Nevertheless, the results of the study should be cautiously interpreted because of the existence of certain limitations and issues that needs attention from future researchers such as the categorization of IT leaders and control groups.

This research opened a "Pandora's box" filled with questions worthy of investigation for future researchers. For example, alternative methodologies that are more robust and reliable should be developed to define firms with superior IT capabilities. Besides, other valid variables and constructs that could possibly influence the link between IT capability and financial performance should be identified and incorporated in future studies. What's more, it could be

insightful to examine the relationship in sublevel to consider from the different organizational characteristics such as industry type and size. Future research is needed but not limited from the above perspectives and hope that this study can be an inspiration for more future attempts to elaborate findings from this research.

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