A MULTILEVEL EXAMINATION OF INFORMATION TECHNOLOGY AND FIRM PERFORMANCE: THE INTERACTION OF INDUSTRY AND FIRM EFFECTS

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Abstract

Although research on the economic value of IT has predominantly focused on firm-level impacts, recent studies have begun incorporating industry-level variables to examine their impact on the value a firm obtains from its IT investments. This trend originated in the aim to offer better contextualized explanations for the differences in value firms obtained from their IT investments across different industries. We present a multi-level model of IT value, in which industry-level and firm-level factors jointly determine the value a firm obtains from its IT investments. By using a hierarchical linear model to examine industry to firm interactions we are able to control for violations of statistical assumptions that are likely to bias cross-level estimates obtained using conventional methods. Our analysis reveals that all of the industry factors we looked at had significant interaction effects with the link between firm-level IT and performance. Specifically, industry concentration, industry growth, and industry outsourcing significantly impact firm-level IT value. More interestingly we find these industry-level IT impacts manifest not only as mean differences between industries, but also as significant interactions with firm-level effects. Initial results from this research-in-progress suggest a multilevel perspective could enrich our understanding of the relationship between IT and firm performance.

Keywords: information technology and firm performance; business value of information technology; industry effects; hierarchical linear modelling; HLM

1 INTRODUCTION

Information technology (IT) has the single largest category of capital investment in the United States (Stiroh 2002). Much research has looked at the impact of this investment upon various measures of firm performance, such as labor productivity, profitability and market valuation, (e.g. Jorgenson 2001, Triplett and Bosworth 2002, Bharadwaj et al. 1996; Brynjolfsson and Hitt 1996; Hitt and Brynjolfsson 1996; Morrison 1997; Anderson, et al. 2006; Aral and Weill 2007; Stiroh 2002; Pilat 2004). Most investigation of IT impacts have, understandably, focused at the locus of decision-making: the firm-level (Rai et al 2006; Barua et al. 2004; Banker et al. 2006; Paulo and Sawy 2006). However, more recently information systems (IS) researchers have pointed out the importance of context (Hong et al. 2013). In the context of firm-level investigations, contextual understanding means firm decisions within an industry context (Chiasson and Davidson 2005).

Despite seeming widespread acknowledgement of the importance of context, such investigations are largely under-explored. While recent IT value research has begun to take notice of this issue, it has not been adequately addressed yet. In their review of IT value research, Melville et al. (2004) propose an important research question: "What is the role of industry characteristics in shaping IT business value?" They also specifically mentioned that the use of industry controls was not a viable means of answering that question. Despite this, researchers, while moving away from using simpler industry dummies to control for industry heterogeneity, have persisted in using industry attributes as controls to measure industry impacts. For example, Chari et al. (2008) controlled for industry capital intensity, uncertainty, concentration, and growth in their study of the impact of firm diversification on the returns from IT investments. Similarly, Melville et al. (2007) inserted industry dynamism and competitiveness into their firm-level production functions. Also, Xue et al. (2012) showed how industry environments moderate the type of performance gains firms are likely to realize thought IT. However, none of these studies used an explicitly contextualized modelling approach such as one supported by multilevel modelling. Explicitly contextualized approaches, such as multilevel or hierarchical models, allows firm-level effects to vary across industries. Such an approach allows researchers to assess both the impact and magnitude of contextual factors and is a major source of expected contribution in this paper.

While the critical role of industry characteristics are starting to being recognized, no formal analysis has been done to identify either how or by how much IT impacts firm performance differs because of industry-related factors. If this was known, researchers would be better able to ascribe reasons for the differences in IT value found across firms. Without this knowledge, the measurement and establishment of performance-related goals from IT investments may be biased. Thus, our research question is:

How do industry characteristics impact firm IT value?

The inability of existing research to provide a basis to differentiate firm-level IT impacts according to the nature and types of industry hinders improvements in the efficient management of IT resources, as well as the achievement of greater accuracy in the measurement of IT impacts, as various questions remain unanswered. This research-in-progress study explores some of these issues using hierarchical linear modelling (Bryk and Raudenbusch 2002), a robust analytic method that is expressly designed to estimate models with nested data structures. We next present the details of our model, followed by the description of the data, the analysis procedures and the results. The paper concludes after a discussion of the implications of the initial results.

2 RESEARCH MODEL

The purpose of the research-in-progress work presented in this paper was to conduct an initial analysis to examine the role industry factors play in the link between IT and firm performance and see if a multilevel model might be a useful lens through which to examine this link. The work presented here is research-in-progress, it represents the results of an initial investigation, not a full study. As such, the research model is somewhat exploratory which we present as a stated proposition and a proposed model to investigate the stated proposition. This is not intended to be interpreted as full-formed hypotheses, but rather an initial empirical attempt to see if such an approach warrants further study.

Strategy literature informs us that a firm's industry has a significant and sustained impact on its performance (Brush et al. 1999; Chang and Singh 2000; McGahan and Porter 2003). Building on prior studies of firm performance in the IS and strategy literature (Chang and Singh 2000; McGahan and Porter 2003), a range of both firm- and industry-level factors were selected for inclusion in our model. Anecdotal evidence and practitioner studies indicate that industries do differ in the extent to which they adopt and use information technology (IT) as well as the effectiveness with which they leverage IT functionalities and capabilities (Farrell 2003; Forman et al. 2003). The firm-level factors that we study are: advertising expenditure, research and development (R&D) expenditure, market share, and IT expenditure. These variables are regularly used in IT value studies, in addition to IT investment, and their utility as important covariates that impact firm performance has been demonstrated often (Bharadwaj et al. 1999; Melville et al. 2007; Chari et al. 2008; Kobelsky et al. 2008). Table 1 lists the variables and their measures, as well as the theoretical rationale for including them in the model. The table also includes the dependent variable used in the study, Tobin's q. This market-based measure of a firm's replacement value has been used in various prior studies (Bharadwaj et al. 1999) because of its advantages over accounting measures that are prone to manipulation and its ability to capture the contribution of IT to a firm's intangible value by improving its product quality, customer and supplier relationships, and knowledge capture. These aspects are part of a firm's competitive advantage, which is considered to be the ultimate measure of the impact of IT on a firm, not operational efficiency (Melville et al. 2004).

Variable	Measure	Rationale/Support	Source
IT	*IT intensity* = IT expenses/Revenue	determinant of firm's intangible value: improved product quality & market orientation, superior customer relationships	Information Week 500 & Compustat
TOBINS	*Tobin's q* = [(Fiscal year-end market value of equity) + (liquidating value of company's outstanding preferred stock) + (current liabilities) – (current assets) + (book value of inventories) + (long term debt)] / book value of total assets	Measure of firm's intangible value; Forward looking measure; less vulnerable to changes in accounting practices	Compustat

Table 1. Firm-Level Variables

Industry attributes affect firm performance in two ways: a) directly, by, for example, affecting access to valued resources or possible competitors, and b) indirectly, by having an impact on the relationship between firm-level variables and firm performance. For example, the link between IT investments and firm profitability could be stronger (i.e. have a more positive slope) in less competitive industries, but be weaker (i.e. have a flatter slope) in more competitive industries. Thus, in addition to including industry-level covariates as direct influences on firm performance, as suggested by prior strategy research, we also take into account findings regarding cross-industry differences in IT use and effectiveness by interacting them with firm-level variables to capture relationships such as the one in the example above.

The following industry-level covariates were used in our model: industry concentration, industry capital intensity, industry growth rate, and industry outsourcing intensity (see Table 2). Concentration indicates the level of competition in an industry, and firms in more concentrated industries are generally able to obtain higher profit margins. The capital intensity of an industry represents entry barriers to newcomers to the industry, and also reduces investment in intangibles.

Variable	Measure	Rationale/Support	Source
HHI	Herfindahl-Hirschman Index. A measure of industry concentration. $HHI_j = \sum_{i=1}^{n} m_{i,j}^2$ where n is the number of firms in the industry and $m_{i,j}$ is the marketshare of the ith firm in the jth industry.	Industries with higher concentration levels: a) share the benefits of IT investment with fewer competitors (Kobelsky et al. 2008; Besanko et al. 2001; Zhao and Zou 2002) b) More concentrated industries by definition have relatively larger firms due larger optimal plant sizes (Curry and George 1983) c) Investments in high fixed cost process changing technologies (such as ERP, CRM, etc.) become more feasible due at larger scales. d) use IT more efficiently (Wimble et al. 2007)	Compustat
GROWTH	*Industry growth* = Mean percentage sales growth for previous and current year	Industries with higher growth rates: a) have lower levels of competitive rivalry; b) use IT to provide economies of scale to support increased transaction volumes (Kobelsky et al. 2008). c) Easier for new firms to enter. Newer firms are more likely to have more up-to-date technology since they are not faced with the switching costs associated with transitions out of less efficient legacy technology (Akeson and Kehoe 2007).	BEA
KINT	*Industry capital intensity* = Total assets/sales revenue	Industries with higher levels of capital intensity: a) have higher barriers to entry (Capon 1990); b) require less investment in intangibles	BEA & US Bureau of Labor Statistics (BLS)
SERVICE	*Industry type* = Dummy variable: Services =1, Manufacturing = 0	a) The value of IT differs across IT-intensive and non-IT-intensive sectors (Mittal and Nault 2009). b) Services firms use more IT than manufacturing firms because they are more information-intensive. (Bowen and Ford 2002)	BEA
OINT	*Outsourcing intensity* = Total outsourcing expenses/sales revenue	Industries with higher levels of outsourcing intensity: a) are more efficient because they have externalized inefficient operations b) IT helps firms better manage and monitor suppliers (Malone et al. 1987)	BEA

Table 2. Industry-Level Variables

The individual impacts of these variables are identified in Tables 1 and 2. Prior research has mainly examined firm- and industry-level impacts independently. In addition to the firm-level variables included in table 1, we also controlled form firm market share, advertising intensity and R&D intensity. The industry factors were chosen primarily on the basis that they have been shown to be important factors, in general, in prior studies of non-IT related firm performance. As a result most, but not all, of the contextual factors we chose were shown in the past to be important regardless of whether IT was included as a factor in the study or not. Since this study focuses on assessing how higher-level (i.e. industry-level) factors influence the impact of IT on firm performance, we list some relevant findings from prior literature under the "Rationale/Support" column in each table. Firm-level studies of IT value have consistently found strong industry effects both with included as binary controls and with industry measures such as concentration (Bharadwaj 2000; Dedrick et. al. 2003; Melville et. al. 2007). Recent evidence from cross-industry studies suggests substantial differences in performance impacts of IT (Strioh, 2002; Cheng and Nault 2007; Wimble et. al. 2007). Recent evidence from practice suggest that companies often benchmark IT practices using within-industry comparisons and that cross-industry comparisons are much more useful (Cullen 2007). Finally, industrial organization theory suggests that industry directly impacts firm-level actions and that firm performance is contingent upon industry conditions (Porter 1985). Thus, we propose that:

Proposition 1: *Industry attributes will have a significant effect on the impact of IT on firm performance.*

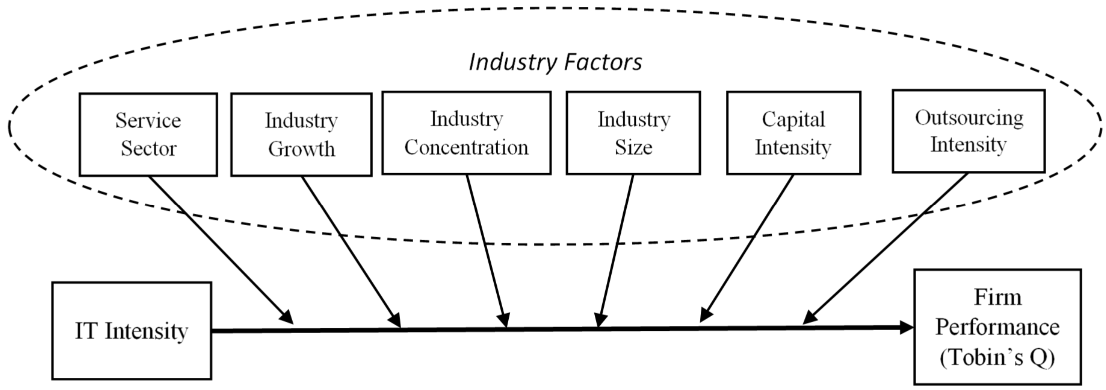

Figure 1. Research Model

3 METHODS

As is often recommended for analysing nested data, we used hierarchical linear modelling (HLM) (Bryk and Raudenbusch 2002). Nested data leads to several problems such as: a) aggregation bias, when a variable has different meanings at different levels, b) misestimating of errors, which occur because observations at different levels are not independent, and c) heterogeneity of regression, where relationships between level 1 units differ across level 2 units (Mithas et al. 2006). These problems can be addressed using HLM. In addition to empirical problems arising from nested data, there is also a problem of inference. An explicitly nested modelling approach avoids logical problems of ecological or individualistic fallacy by expressly modelling the phenomenon in question as having multiple levels of aggregation.

In this context, firms (level 1 units) are aggregated (i.e. nested) within industries (level 2 units); the implication here is that within-industry (i.e. across-firm) variation in performance must take into account industry membership. Standard regression, OLS or otherwise, typically assumes that the association between IT and performance are identical across industries. HLM does not make this assumption, in fact it assumes the association varies. HLM provides an estimate of the variance in firm performance connected with between-industry differences in attributes such as industry concentration. Such analysis is not possible when industry summary statistics of these attributes are used as outcomes in standard ANOVA or regression models.

3.1 Data

Firm-level data on the IT investments of 1413 firms from 1998 to 2004, together with accounting data from compustat, is used to test our hypotheses. The firms were part of 290 industry-years. The IT investment data, is obtained from a survey of IT executives carried out by Information Week, while the accounting data is from Compustat. The Information Week data has been used extensively in other studies (Kobelsky et al. 2008; Chari et al. 2008; Liu and Ravichandran 2008). Industry-level data was obtained from the US Bureau of Economic Analysis (BEA) and US Bureau of Labor Statistics (BLS), with the exception of the industry concentration measures. Industry concentration measures were estimated from Compustat in order to provide annual estimates and estimates for services industries. Industry concentration measures are not available from the U.S. Census Bureau on an annual basis, nor in HHI form for service industries. It is important to note that while the time period for this data might seem dated, this data allows us to field test something which is discussed often, role of industry effects of firm-performance. Use of ostensively old data is common in archival studies on business value of IT. In fact, several recent studies in prominent journals use data much older than what we use (Tambe and Hitt 2013; Dewan and Ren 2011) what matters is if the research question in enduring and if the data allows you to test the question. While the data is older than would be found in survey or experimental research, the important is the theoretical question is enduring.

3.2 Analysis

We used full maximum likelihood and an empirical Bayes procedure to estimate the model in HLM v. 6.05a (Raudenbusch et al. 2002). The model was estimated in an incremental approach, which allows model testing. First, a fully unconditional model was tested where there were no covariates at either level (Model 1). This helped evaluate whether sufficient variation existed in firm performance across the two levels. Partitioning the variance in this way allowed the computation of the intra-class correlation (ICC), which is a measure of the relatedness or dependence of nested data. ICC is equal to $\sigma 2/ \sigma 2 + \tau$, where $\sigma 2$ is between-industry variation and τ is within-industry variation.

Next, we estimate a random coefficients model, where we add firm-level covariates (Model 2). The significance of random or fixed effects can be assessed by comparing the deviance (-2 log likelihood criterion) between the two nested models, using a $\chi 2$ distribution. The degrees of freedom for this test will be the difference in the number of parameters between the two models. In the next step, we include industry-level covariates (Model 3), which means that we are allowing slopes and intercepts to vary across industries. Thus, in this level 2 model, the intercepts and slopes of the level 1 model are estimated using industry-level covariates. It is worth noting that, because this paper is focused on estimating the impact of industry-level factors on the IT-firm performance relationship, we will be introducing industry-level covariates to explain the IT slope only.

4 RESULTS

Table 3 depicts the correlation matrix at the firm-level, with industry covariates included. Table 4 shows the industry-level covariates. Note that the correlations between the industry covariates are different between the two tables, due to the inherent nesting of industry-level measures viewed from a firm-level. The impact of the nesting on the correlations is why HLM is needed to conduct cross-level studies. To reduce multicollinearity, the industry-level variables were centered using group mean centering, while the year-level variables were centered using grand mean centering. Grand mean centering is appropriate for assessing whether industry-level predictors provide incremental prediction of firm performance over and above firm-level predictors (Hofman and Gavin 1998, p. 634) [quoted in Ang, et al. 2002].

	tobins	mktshr	ADI	RDI	IT	Serv	Growth	HHI	KINT	Ind. Size	OINT
tobins	1										
mktshr	-0.015	1									
ADI	0.121	0.001	1								
RDI	-0.010	-0.015	-0.005	1							
IT	0.180	-0.049	-0.006	-0.013	1						
Serv	-0.018	-0.083	-0.029	-0.029	0.172	1					
Growth	-0.014	0.029	0.007	-0.009	-0.019	0.244	1				
HHI	-0.023	0.327	-0.074	-0.005	-0.029	-0.131	0.122	1			
KINT	0.003	0.167	-0.015	0.004	-0.089	-0.334	0.004	0.223	1		
Ind. Size	-0.007	-0.236	0.079	-0.003	-0.022	0.334	0.190	-0.146	-0.266	1	
OINT	0.047	0.165	0.116	0.025	-0.147	-0.693	-0.166	0.294	0.127	-0.426	1

Table 3. Firm-Level Correlation Matrix

	Serv	Growth	HHI	KINT	Size	OINT
Serv	1					
Growth	0.135	1				
HHI	-0.086	0.116	1			
KINT	-0.086	0.070	0.246	1		
Size	0.245	0.120	-0.113	-0.199	1	
OINT	-0.595	-0.076	0.242	0.211	-0.351	1

Table 4. Industry-Level Correlation Matrix

Table 5 lists the results. The largest percentage of variation in firm performance lies within industries (89.29%), while a smaller but substantial proportion lies across industries (10.71%). The significance of the deviance difference statistic between the models indicates that the additional variables significantly improved the model compared to the original one. The significance of the industry-level random effect (χ^2 =410.559, $p<0.05$) indicates that there is significant variation between industries in both average IT impacts and the rates at which performance improves.

This hierarchical analysis offers a more complete and accurate estimation of the impact of IT intensity. For example, while IT intensity is found to have a substantial impact on firm performance (Model 2, Table 5), the hierarchical analysis (Model 3, Table 4) reveals how these impacts are decomposed into the various industry factors. The results of Model 3 indicate that IT enhances firm performance on average, but the effect is stronger when the industry is: a) growing, b) more concentrated (i.e. less competitive), c) uses outsourcing heavily, and d) a service industry.

The model illustrates that industry-level effects to IT are likely to manifest through interaction with firm-level impacts. These findings points to the role of IT for facilitating cross-border and inter-firm transactions. It is possible that firms that engage in higher levels of outsourcing are able to use their IT investments more efficiently. Thus, this study could possibly be a test of the claim to that IT lowers transaction costs (Gurbaxani and Whang 1991).

Variable	**Model 1**	**Model 2**	**Model 3**
Intercept (γ_{000})	1.197**	1.195**	1.196**
	(0.072)	(0.073)	(0.075)
Firm-level effects:			
Market Share (γ_{100})	-	-.421	0.145
		(1.264)	(1.194)
Adv. Intensity (γ_{200})	-	6.010**	7.146**
		(2.811)	(2.652)
R&D Intensity (γ_{300})	-	-0.013	-0.017
		(0.017)	(0.016)
IT Intensity (γ_{400})	-	9.402**	18.058**
		(1.352)	(2.086)
Industry-level effects:			
Service industry (γ_{010})	-	-	0.175
			(0.195)
Industry growth rate (γ_{020})	-	-	0.007
			(0.903)
Industry concentration (γ_{030})	-	-	-0.264
			(0.246)
Capital intensity (γ_{040})	-	-	0.754
			(0.692)
Industry Size (γ_{050})	-	-	-0.000
			(0.000)
Cross-level effects:	**Model 1**	**Model 2**	**Model 3**
Service Industry*IT Intensity (γ_{410})	-	-	36.039**
			(6.531)

Growth*IT Intensity (γ_{420})	-	-	65.797** (27.814)
Market Conc.*IT Intensity (γ_{430})	-	-	60.820** (16.081)
Outsourcing Int.*IT Intensity (γ_{440})	-	-	79.123** (23.280)
Industry Size*IT Intensity (γ_{450})			-0.0001** (0.0001)
Deviance (-2 log likelihood)	6245.832	6191.655	6048.617
Degrees of freedom	4	8	18
Deviance difference	-	$\chi^2 = 54.177$**	$\chi^2 = 143.038$**
σ^2	4.59256	4.38544	3.89377
τ	0.34464	0.38604	0.46721
Variance Decomposition			
Across Firms (ICC = $\sigma^2/ \sigma^2 + \tau$)	93.08%	91.91%	89.29%
Across Industries (1-ICC)	6.92%	8.09%	10.71%

Table 5. HLM Results

5 CONCLUSION

Again, the purpose of the research-in-progress work presented in this paper was to conduct an initial analysis to examine the role industry factors play in the link between IT and firm performance and see if a multilevel model might be a useful lens through which to examine this link. While these factors, such as industry growth and concentration, have often been proposed as important determinants of firm value, a rigorous test of their contribution has not been done. Hence, it was not known how much of the value firms derive from IT is attributable to industry-level attributes. Further, the nature of these macro variables and their influence on IT impacts is essential for developing superior management processes and measurement instruments to assess IT performance impacts. In this study, we used hierarchical linear modelling to examine these embedded impacts and to establish the role of industry-level variables in IT performance.

The study is the first to examine the impact of industry-level variables on the impact of IT on firm performance, while controlling for aggregation effects and cross-industry variation in IT use. There are two key contributions of this research are 1) assessing the role various industry-level characteristics play in affecting the impact of IT on firm performance; and 2) presenting a methodology whereby the contingencies that impact the value firms obtain from IT can be assessed.

Our results indicate that industry level factors do have a significant influence on the value that a firm realizes from its IT investments and that a substantial portion of the impact of IT is due not to direct effects, but rather contextualized impact resulting from the interplay between IT and environmental factors. This study's results imply that while measuring the impacts of information systems, it is essential to include contextual industry factors, as they influence the impact of IT.

Further research could extend this study in two ways. First, additional industry-level variables that are known to influence the impact of IT on firm performance, such as dynamism, uncertainty, the level of regulation, and the role of IT in the industry (i.e. automate, informate up or down, transform), could be used as additional covariates. Second, a panel approach examining effects over time would also seem worthwhile. We feel this research-in-progress study provides substantial evidence as to the value of a multilevel approach to IT business value research and provides evidence as to the importance of including industry factors as explanatory factors rather than control factors.

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