

Augmenting productivity analysis with data mining: An application on IT business value

Simon K. Poon*, Joseph G. Davis, Byounggu Choi

School of Information Technologies, University of Sydney, NSW 2006, Australia

Abstract

In this paper we use a large firm-level dataset to extend previous studies by augmenting the endogenous growth accounting framework with a data mining technique to analyze the complex relationships between the use of IT and organizational practices. There is emerging evidence of recent emphasis on organizational factors and a greater shift towards “IT complementarities” in which value addition is linked to combining complementary organizational practices with IT investments. Our findings indicate that the set of interrelated organizational practices that complement positively to IT use is different from the set of practices hindering IT use. The presence of clustering among organizational practices clearly implies that some combinations of practices make it difficult to precisely empirically examine. We have found that our technique was able to show some organizational factors may have different pathways to affect organizational performance and such organizational practices have often been overlooked but can play a weak yet non-trivial role in production and organizational processes.

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1. Introduction and motivation

In the mid-1980s, Robert Solow¹ and others argued that there was insufficient evidence to link the massive investments in information technology (IT) to productivity growth. This phenomenon which came to be known as the productivity paradox has since emerged as an important research topic for economists, information systems researchers, and management theorists. Since then, a range of models and methods has emerged (Brynjolfsson & Hitt, 1996; Lehr & Lichtenberg, 1998). However, there are still considerable variations in the findings on produc-

tivity impacts attributable to IT investments. Stiroh (2004) analyzed the extensive econometric literature on the economic impact of IT and found that much of the observed variation in estimates of the impact attributable to IT is due to differences in model specification and analytical technique.

Earlier disappointing results suggested that while IT was a critical technology in organizations, it was modeled inadequately (Brynjolfsson & Yang, 1996). Recent studies have suggested that important organizational practices were often omitted in the productivity analyses, and the time-consuming nature of many organizational changes would take a much longer time to observe (Brynjolfsson & Hitt, 2003). These studies have highlighted that more nuanced analytical techniques are needed to enhance our understanding of the complementarities of the technology-organizational phenomenon.

* Corresponding author. Tel.: +61 2 9351 4920; fax: +61 2 9351 3838.
E-mail address: spoon@it.usyd.edu.au (S.K. Poon).

¹ Solow (1987) argued that, “You can see the computer age everywhere but in the productivity statistics”.

The concept of “complementarities”² can offer a useful perspective to study the complex relationships between organizational practices and the use of IT. In 1990s, Milgrom and Roberts (1990, 1995) proposed the concept of “web of complementarities” which marked a paradigmatic in conceptualizing other complex dynamics among organizational practices. Previous studies have contributed to our understanding of whether and how complementary relationships among organizational practices lead to significant increases firm-level performance. However, the model construction is still a critical problem in studying complementarities due to the following three reasons. First, complementary factors need to be considered simultaneously. Second, the levels of impacts can vary significantly between different configurations. Third, there can be many possible complex forms of relationship structure among the complementary factors. This is due to the fact that model construction requires identification of potential input factors, in addition to the relationship structure of those potential factors. Therefore, there is a need to model the complex inter-relationship structures of the potentially complementary factors.

In this paper, by combining the use of data mining and econometric techniques, we attempt to explore the impacts of complementary relationships between a large set of organizational practices and use of IT at the firm-level. The aim is to highlight a set of fundamental issues that are critical to understanding the mechanisms by which IT interacts with organizational practices. We propose a new approach to deal with the fractal like, interlocking nature of organizational practices and IT, which can potentially produce higher returns.

2. Literature review

The role of organizational routines is closely related to the knowledge capital of a firm. A number of recent studies have found that much larger IT impacts were realized when IT investment was combined with organizational changes such as new strategies, new business processes and practices, and new organizational structures (Pilat, 2004). Many factors are found to have different ways of affecting the organizational process, and in turn influencing the performance. Barua, Sophie Lee, and Whinston (1996) presented a theory called “business value complementarity”

² The original concept of complementarities was first developed by Edgeworth (1881), it defines activities that are complements if doing (more of) any one of them increases the returns to doing (more of) the others. The notion of complementarities discussed here can be represented by the “supermodularity” of a function with respect to two or more complementary variables (Topkis, 1978). Supermodularity dictates that the sum of the increases in the value of a function when the levels of the complements are changed one at a time would be less than the increase in the function’s value when the levels are changed simultaneously. In other words, if complementarities among activities exist, then the gains from increasing every component are larger than the sum of the individual increases.

and argued that IT investments and organizational reengineering cannot succeed if implemented in isolation. Therefore, the synergies among various organizational practices are not whether an organization adopts a particular work practice but rather how that work practice is implemented in conjunction with other complementary practices.

Many researchers have investigated complementary relationship among various business practices. For example, Black and Lynch (2001) argued that, until recently, there has been very little direct analysis of the impact of workplace practices on productivity. They found some synergies among various workplace practices but concluded that the important issue is not whether an organization adopts a particular work practice but rather how that work practice is implemented in conjunction with other complementary practices. Bresnahan, Brynjolfsson, and Hitt (2002) surveyed approximately 400 large firms to obtain information on aspects of organizational structure such as allocation of decision rights, workforce composition, and investments in human capital. They found that these work practices are correlated with each other, and argued that these practices are part of a complementary system. However, no unifying procedure has been developed for analyzing complementarity structure among complementary factors.

2.1. Analytical methods in modeling complementarities

Athey and Stern (1998) argued that analyzing complementarity can be achieved in two different ways. One approach is based on correlation among organizational practices (e.g. Arora & Gambardella, 1990). This approach tests conditional correlations based on the residuals of reduced form regressions of the organizational practices on observable exogenous variables (Holmstrom & Milgrom, 1994). However, although this approach can provide a useful way of analyzing complementarities between practices statistically, it cannot serve as a definitive test. Estimated correlations between residual terms may be the result of common omitted exogenous variables or measurement errors; hence, it does not guarantee that combinations of the practices lead to enhanced output (Lokshin, Carree, & Belderbos, 2004). This approach is only able to disentangle interactions between two variables.

A second approach, the so-called production function approach, relies on a regression of a measure of productivity on a set of regressors, such as interaction effect, as estimates of complementarity parameters. Unlike the correlation approach, this approach can provide a statistical resolution for complementarity. This approach has been widely used in recent empirical work to test for complementarity between organizational practices in various contexts (e.g. Bocquet, Brossard, & Sabatier, 2007; Ichniowski, Shaw, & Prennushi, 1997).

Athey and Stern (1998) pointed out two empirical challenges in analyzing the interactions between elements of organizational practices in production function analysis.

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