An Application of DEA to Efficiency Analysis of Controls in B2B Systems

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Abstract

Major benefits derived from EDI depend upon the use of appropriate controls for EDI to overcome potential risks and exposures inherent with integration and utilization of the system. As many resources and high degree of skill are required for the implementation of EDI controls, the design of the controls should proceed according to the extent of EDI implementation and performance that the controls are related to. This paper gives a description of a data envelopment analysis (DEA) model for efficiency analysis of the controls for the specific context of electronic data interchange (EDI). This study uses a data envelopment analysis model to analyze the efficiency of EDI controls in the context of financial and trade applications. The DEA model uses the eight variables of formal or automated EDI controls as input and four variables of EDI implementation and performance as output. Automated controls are more efficiently utilized in financial applications than in trade applications, while formal controls are more efficiently used in trade applications than in financial applications.

Keywords:

EDI, EDI controls, Data Envelopment Analysis (DEA), EDI implementation, EDI performance

Introduction

For many companies, the design of efficient control systems after innovating organizations using information technology is important [19], but it has been a difficult task. Given the high cost and resources needed to develop and maintain controls for sophisticated system such as EDI [1, 13], it needs to analyze the efficiency of EDI control systems. The determination of the level of EDI controls, however, receives only limited attention in academic research as well as in business. There has not been a single investigation into the efficiency of controls for the implementation of EDI system. This paper gives a description of EDIDEA (EDI-Controls Efficiency Analysis using Data Envelopment Analysis), a data envelopment analysis (DEA) model for efficiency analysis of EDI controls. The purpose of the study is to suggest a normative approach toward diagnosing the efficiency of EDI application rather than examining the theoretical relationships between controls and implementation (or performance). This study uses a data envelopment analysis model to analyze efficiency of EDI controls in the context of financial and trade applications as well as various input (formal and automated EDI controls) and output (EDI implementation and performance) combinations. The efficiency level of EDI controls can be compared across different applications and classes of controls.

DEA Approach

Data Envelopment Analysis (DEA) is used to analyze the efficiency of EDI controls. Specifically, the present study used radial improvement and constant returns to scale DEA model of Charnes, Cooper, and Rhodes (CCR) [5] model. The radial model attempts a radial improvement in both inputs and outputs. Warwick-DEA software by Thanassoulis and Emrouznejad [20] is used to code the DEA model of the personal computer version.

DEA is a methodology based on the mathematical programming that produces the relative efficiency of Decision Making Units (DMU) (e.g., individuals, organizational units). DEA optimizes on each individual observation providing a discrete piecewise frontier that represents the set of Pareto-efficient DMUs. DEA optimizes the performance measure of each DMU and focuses on individual observations, while the same estimated equation is assumed to apply to each DMU in parametric analysis (e.g., regression analysis, discriminant analysis).

Theoretical Framework

EDI controls are the activities to safeguard assets, maintain data integrity, accomplish organizational goals effectively, and consume resources efficiently [10, 21]. EDI controls in this study focus on asset safeguarding, integrity, and confidentiality.

As the implementation of system proceeds, tracking and control mechanisms are necessary to ensure the continuity of EDI services as the transaction volume and the speed of processing increases and human intervention reduces. "Control assurance" should be provided to various stakeholders including internal users, trading partners, and

decisions regarding further implementation of system can be made [4, 14]. In the case of IOS (interorganizational system), companies, especially influential ones, demand trading partners to establish an "adequate" level of controls, specified in trading partner agreements, before connecting their system to trading partners' systems [11, 17]. Possible disclosures or alterations of transmitted messages made by VAN, by an unauthorized third party or trading partners should be prevented.

In this study, it is assumed that EDI implementation and performance depends on the design EDI controls as the latter is believed to increase the potential for the former. Given this relationship between EDI controls, and EDI implementation or performance, DEA is used to analyze efficiency in the usage of EDI controls where EDI controls and EDI implementation (and performance) are treated as input and output, respectively.

Input of EDIDEA

In this study, controls can be classified into two important dimensions: formality and automation. Formal controls are established by management and based on written procedures to:

- protect applications from errors and unauthorized access,
- ensure that communication is accurate and secure,
- ensure that VAN service providers provide security of EDI messages and communication processes, and
- ensure that trading partners provide security and integrity of communication.

Formal controls have four modes, each of which pursues one of these objectives. Automated controls indicate the degree to which such procedures and methods are used to detect and correct errors during input, process, and output of data and ensure security and authentication software to protect the systems from unauthorized access and computer abuse. Formal controls are procedural and fundamental in that they delineate preventive, detective and corrective actions (including operation and maintenance of automated controls) to address security issues across all EDI systems. They differ from automated controls that just represent the usage of security programs and embedded routines. Automated controls also involve the VANs and trading partners in protecting system integrity. Hence there are also four modes of automated controls: application, communication, VAN, and trading partner controls.

Measures for EDI controls are newly developed based on various sources [4, 10, 11, 12, 15, 17] (Table 1). The first version of measures of EDI controls was modified through an interview with ten EDI practitioners (one from each company) who are cognizant of managerial and technical aspects of EDI controls. They were measured on seven-point Likert-type scales (1 = Totally disagree, 7 = Totally agree). EDIDEA uses eight variables for input variables; four variables for formal and automated controls, respectively. Only qualitative measures are used, as it is difficult to measure the use of EDI controls quantitatively (e.g., labor cost of security staffs, investment cost of security software).

Table 1: Input and Output Variables
(NA: Because the variable is composed of a single item, no reliability and validity analysis is conducted.)

Input or Output	Subclass	Variables (Cronbach Alpha)	Items	Sources
Input	internal formal controls	internal formal application controls (alpha = 0.7102)	● system change control by authorization (FC1) ● integrity check of the message before processing in the application (FC2) ● transaction log for the possible errors and collapse (FC3) ● appropriate system login procedures using password (FC4)	[4], [10], [11], [15]
		internal formal communication controls (alpha = 0.7907)	● integrity check after generating EDI messages (FC5) ● authentication of trading partners after receiving EDI messages (FC6)	
	external formal controls	external formal VAN controls (alpha = 0.8605)	● back up and recovery plan by VAN (FC7) ● retransmission after correcting erratic messages by VAN (FC8) ● dispute reconciliation procedures by VAN (FC9) ● access control on network by VAN (FC10) ● mailbox access control by VAN (FC11)	
		external formal partner controls (alpha = 0.7828)	● back up and recovery plan by trading partners (FC12) ● retransmission after correcting erratic messages by trading partners (FC13) ● dispute reconciliation procedures by trading partners (FC14) ● access control on network by trading partners (FC15)	

	internal automated controls	internal automated application controls (NA)	● programmed integrity check before processing in application systems (AC1)	
		internal automated communication controls (alpha = 0.7179)	● automated data integrity check before transmission of EDI messages (AC2) ● automated authentication of trading partners using message code (AC3)	
	external automated controls	external automated controls by VAN (alpha = 0.7765)	● automated transaction log for EDI messages by VAN (AC4) ● error message tracing and error reporting by VAN (AC5) ● digital signatures(message authentication code) provided by VAN (AC6)	
		external automated controls by trading partners (alpha = 0.6673)	● automated transaction log for EDI messages by trading partners (AC7) ● error message tracing and error reporting by trading partners (AC8) ● digital signatures(message authentication code) provided by trading partners (AC9)	
Output	implementation	integration (NA)	● integration of EDI in five application systems	[16], [18]
		utilization (NA)	● utilization of EDI in five application systems	
	performance	improved relations (alpha = 0.8910)	● improvement of relationship by reduction response time (REL-1) ● improvement of relationship by reduction of delay from errors (REL-2) ● improvement of trust by enhanced authentication of message contents (REL-3) ● improvement of relationship by reduction of omission or inaccuracy in transmission (REL-4) ● maintenance of trust by protection of messages from modification by third parties (REL-5)	[2], [3], [8]
		influence on productivity (alpha = 0.8681)	● increase in efficiency of interdepartmental transaction processing (ADV-1) ● increase in accuracy by reduction of paper work (ADV-2) ● reduction of transaction processing costs (ADV-3)	

Output of EDIDEA

EDI implementation has two dimensions, *integration* and *utilization*. Integration is measured by the average level of integration of application systems which respondents selected, as they believe to be very closely connected with EDI [18]. The scope of applications that are related to EDI is mostly limited, although they have many organizational tasks. The implementation of EDI applications of EDI adopters at the organizational level can be represented by five tasks (e.g., import/export authorization, firm banking, cash management system, cash transfer) that are selected by respondents. A seven point Likert-type scale is used to measure *integration*.

The *utilization* is measured by the average level that a company uses EDI in the five EDI applications (i.e., the same applications selected to measure integration) that can be processed through other means. It is the proportion of a firm's information exchange and processing that are handled through EDI in each of EDI applications.

The measures for EDI performance are based on various EDI survey results [2, 3, 8] and EDI management and controls [4, 6, 11, 15]. There are two dimensions of EDI performance; improved relations and influence on productivity. The former means the reinforcement of ties with a business partner and improved customer service, while the latter is related to cost reduction and increased productivity of work processes.

Hence, EDIDEA uses four output variables (two variables each for EDI implementation and performance, respectively) in this study; integration, utilization, improved relations, and influence on productivity. The measures for the implementation and performance are described in Table 1.

EDI Applications

The tactical plan of controls may differ according to the timeliness and accuracy requirement of applications. EDI adopters perform various applications using EDI. These applications can be classified into several groups according to the similarity of tasks. This study classifies EDI application into two parts; financial and trade applications [7, 9].

Financial and trade applications are selected as they are generally different in security and control requirements: the former which deals with transactions of monetary value has higher vulnerability than the latter. The latter involves a greater number of document standards regarding the process of trade documents and order processing than the

former. The specific names of each application performed by EDI in each category are:

- banking: Firm Banking, Cash Management System, Cash Transfer (Electronic Funds Transfer)
- trade business: Import/Export Authorization, Import License Open, Master License Open, Local License Open, Exchange/Negotiation, Tariff

Data Collection

The main data collection method is structured interviews of respondents from EDI adopters. One or two members of EDI staff or managers took part in the interview. They were believed to have sufficient knowledge about EDI implementation. A total of 110 usable responses comprised the final usable sample. The unit of analysis is individual EDI adopting company.

One of goal of this study is to analyze the difference in control efficiency between financial and trade applications. 110 firms can be divided into four groups according to whether they implement financial and trade applications. Eight EDI adopters implement both financial and trade applications. These eight firms as well as six firms that have not implemented neither of the two applications are excluded from further investigation in order to examine the difference between financial and trade applications. The total number of firms in the sample is 41 financial EDI applications and 39 trade applications. DMU is an individual EDI adopter.

Results and Discussion

Reliability and validity tests were performed for the collected data. The Cronbach's alphas are presented in Table 1. All scales exceed 0.6, which shows moderate to high reliability. The content validity of the items was established through the adoption of constructs that have been validated by other researchers and a pretest with 10 IS professionals. Further, extensive precautions were taken during the previous stages of development and pilot testing of the items.

As a result of separate exploratory factor analysis on the items that measured the EDI controls, and on the items for EDI implementation and performance, the items converged on appropriate variables, as originally envisaged. Based on the results on principal component analysis, the items that loaded on multiple constructs or had low item-to-construct loading (factor loading values lower than 0.5) were abandoned from further analysis. The results generally show that each item loaded higher on its associated variable, which confirm convergent and discriminant validity of measures. The final items are suggested in Table 1.

Separate efficiency analyses were applied for financial and trade applications, respectively. The percentage of efficient firms and average efficiency are presented in Table 2. This indicates that there exist slightly more efficient firms in financial applications than in trade applications. More EDI adopters use EDI controls efficiently in financial applications, which indicates firms are closer to the efficiency frontier than in the case of trade applications.

Table 2: DEA Efficiency Results

Application	Financial Applications	Trade Applications
number of efficient firms (percentage)	23 (56.1)	15 (38.5)
number of inefficient firms (percentage)	18 (43.9)	24 (61.5)
average efficiency of inefficient firms	0.923	0.902

Table 3 shows the number of efficient firms and average efficiency when specific classes of input and output variables are used. Input variables are divided into two classes, formal and automated controls, and each class has four variables. Output variables are categorized as two classes, EDI implementation (integration, utilization) and EDI performance (improved relations, influence on productivity). When formal controls are used as input, the number of efficient firms and average efficiency are higher in trade applications than in financial applications. However, the number of efficient firms and average efficiency are higher in financial applications than in trade applications when automated controls are used as input.

As the statistical significance of the difference between applications needs to be shown, the average efficiencies are produced and the paired Wilkoxon Test is performed to see whether average efficiency is different (Table 4). Table 4 indicate that the differences between financial and trade applications do exist and are significant: formal controls are used more efficiently in trade applications than in financial applications while financial applications use automated controls more efficiently than trade applications do.

A possible explanation is that EDI adopters depend more on the automated controls by VANs or "hub" companies rather than on controls developed by themselves as the number of EDI documents and trading partners increases. This is more the case in financial application which demands strict standards of security and integrity in system implementation and performance in transactions than in trade applications. The reliance on the automated controls provided by VANs and trading partners and relatively great necessity and perceived benefits of these controls make the automated controls in financial applications more efficient than in trade applications.

Table 3: Average Efficiency in Specific Class of Input and outputs

(Number in parenthesis indicates the number of efficient firms.)

Application	Financial Applications		Trade Applications	
Output Class / Input Class	implementation	performance	implementation	performance
formal controls	37.33 (2)	52.13 (3)	57.31 (5)	72.76 (4)
automated controls	71.97 (7)	76.23 (11)	49.14 (5)	72.13 (7)

Table 4: Wilkoxon Test of Efficiency Difference between Applications

Input Class	Average in Financial Applications	Average in Trade Applications	Wilkoxon Z	Significance
formal controls	31.76	39.70	-2.223	0.026
automated controls	43.20	32.60	-2.844	0.004

In trade applications, the security requirements of system are not as high as in financial applications to require an investment on automated controls. Although automated controls are not as needed due to less strict requirements for security, formal controls are consistently applied due to the strong influence of government trade law and procedures. The reliance on formal EDI controls by external parties (i.e., government, VANs) leads to low investment in control implementation by EDI adopters and a relatively high perceived efficiency of formal controls.

Conclusions and Implications

The implementation of control procedures in EDI is probably the major management issue. Given that the usage level of controls is positively related to the cost of controls, the efficiency analysis of control usage becomes important. This paper describes EDIDEA, the application of DEA on the efficiency analysis of EDI controls. Input and output of EDIDEA are EDI controls, and EDI implementation and performance, respectively. EDIDEA performs the efficiency analysis of formal and automated control procedures and analyzes the efficiency of EDI controls in the context of financial and trade applications. Eight variables of EDI controls and four variables of EDI implementation and performance are used as input and output, respectively. Automated controls are more efficiently utilized in financial applications than in trade applications, while formal controls are more efficiently used in trade applications than in financial applications.

EDIDEA enabled a series of analyses of the difference in the efficiency in various combinations of inputs and outputs and the amount of reduction needed in specific mode of controls. Although EDI controls have been considered as important by practitioners, few studies verify their efficiency. Management can be convinced of the effect of financial and trade applications on the efficiency of security and integrity controls and adjust the investment of resources to make the control systems in the applications efficient.

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