The Impact of Information Technology on Coordination Costs: Implications for Firm Productivity

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Rowan University

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THE IMPACT OF INFORMATION TECHNOLOGY ON
COORDINATION COSTS: IMPLICATIONS FOR
FIRM PRODUCTIVITY

Namchul Shin
Rowan University

Abstract

Most information systems (IS) research has examined the impact of information technology (IT) on the organization of economic activities based on the theoretical speculation that IT reduces coordination costs and improves coordination of economic activities. This theoretical speculation, however, has not been empirically analyzed in the IS field. The value derived from IT that reduces coordination costs has also not been considered in the studies on IT productivity gains. This study empirically examines the relationship between IT and coordination costs and the relationship between IT and firm productivity, considering coordination as a factor of production. The results indicate that IT is strongly associated with a decline in coordination costs and that IT and coordination make a substantial and statistically significant contribution to firm output. Based on the results, the conclusion reached is that IT contributes to firm output by reducing coordination costs and improving coordination; that is, making a higher level of coordination more efficient.

Keywords: Information technology, coordination costs, productivity, information processing, IS budgets, production function.

1. INTRODUCTION

Information technology (IT) has profoundly changed the way that business is conducted. With the use of IT, organizations radically redesign their business processes. IT is also radically restructuring the market by altering customer-supplier relationships. These changes derive from IT, which enables better information processing, sharing, and faster responsiveness, thereby improving coordination of the economic activities between separate units of an organization and across organizations. Most information systems (IS) research (Bakos and Brynjolfsson 1993; Brynjolfsson et al. 1994; Clemons and Reddi 1992; Gurbaxani and Whang 1991; Malone et al. 1987, 1989) has examined the impact of IT on the organization of economic activities based on the theoretical speculation that IT reduces coordination costs and improves coordination of the economic activities critical to the best use of resources and the delivery of goods and services. This theoretical speculation, however, has not been empirically analyzed in the IS field.

Most previous studies on IT productivity gains have considered only the value derived from IT which improves capital and labor efficiency (Brynjolfsson and Hitt 1993, 1996; Lichtenberg 1993; Loveman 1994). The value derived from IT that improves coordination of economic activities has not been considered in the studies. But the ability of IT to reduce coordination costs and improve coordination of economic activities can contribute to firm productivity. Since coordination is necessary for a given level of firm output, and a higher level of coordination can contribute to an increase in firm output, IT contributes to firm productivity by reducing coordination costs and improving coordination of economic activities, that is, by making a higher level of coordination more efficient. Thus,
the value derived from IT that reduces coordination costs, thereby improving coordination of economic activities, should be considered when examining the relationship between IT and firm productivity.

This paper provides an empirical analysis of the relationship between IT and coordination costs based on the previous IS research. This paper also uses the information processing theory (Galbraith 1973, 1977) to provide an empirical analysis of the impact of IT on firm productivity, considering coordination (costs) as a factor of production. Using the microeconomic production theory, an equation model is derived for the empirical analysis of IT impact on firm productivity.

2. **THEORETICAL BACKGROUND**

2.1 **IT and Coordination Costs**

Organizations need to process information in order to coordinate various economic activities. In today’s complex and uncertain environment, the costs of information processing and sharing are enormous. According to the previous studies (Gurbaxani and Whang 1991; Malone et al. 1987, 1989), IT greatly reduces information processing costs by providing better means of information gathering and processing, monitoring, and negotiating and enforcing contracts. Coordination costs refer to all of the information processing costs necessary to integrate the various economic activities of separate units of an organization and between separate organizations. Coordination costs incurred within an organization include the costs involved in acquiring and processing information for decision-making, accounting, planning, monitoring, and control processes. Coordination costs incurred in a market include the costs of searching and selecting suppliers, and negotiating and enforcing contracts (Gurbaxani and Whang 1991; Malone et al. 1987, 1989).

According to Malone et al. (1987), IT is widely used for coordinating economic activities and decreases the unit costs of coordination through the following three effects:

1. **Electronic communication effect**: IT decreases information processing costs by allowing more information to be communicated in the same amount of time or by allowing the same amount of information to be communicated in less time.

2. **Electronic brokerage effect**: IT decreases the costs of the product selection process by increasing the number of alternatives and by increasing the quality of alternatives selected.

3. **Electronic integration effect**: IT reduces inventory holding costs by linking the supplier’s and the buyer’s inventory management processes and making the supplier’s just-in-time delivery possible.

Gurbaxani and Whang also argue that IT can affect the underlying cost structure of a firm since this cost structure is closely related to the acquisition of information. According to them, IT reduces transaction-processing costs, including order-processing and inventory-related costs. IT also reduces costs related to control by providing cost-effective monitoring and performance evaluation devices. IT decreases the costs of documentation and communication, and reduces decision-making costs by providing cost-effective means of acquiring and processing relevant information.
2.2 IT, Coordination, and Firm Output

The relationship between coordination and organizational performance has been reviewed by organizational researchers (Cheng 1983, 1984; Hage 1980; Lawrence and Lorsch 1967). These researchers regard coordination as a necessary condition for effective organizational performance. Viewing the organization as an information-processing system, Galbraith (1973, 1977) argued that the primary function of an organization is to process the information for decision making needed for a given level of performance. Egelhoff (1982) also considered information processing as an important aspect of organizational performance.

Coordination refers to all of the information processing necessary to integrate various economic activities. From an information processing perspective, Cheng (1984) argued that coordination is associated with a given level of organizational output performance: the higher the level of coordination, the better the organization can synthesize information into the organizational knowledge needed for better organizational output performance. According to Lawrence and Lorsch, coordination also aims to achieve unity of effort among various subsystems in the accomplishment of the organization’s task, which is a complete input-transformation-output cycle involving at least the design, production, and distribution of some goods and services.

The above organizational research agrees that a higher level of coordination can improve organizational output performance since coordination is a necessary condition for a given level of firm output performance. Since a higher level of coordination requires large coordination expenses, and since coordination can be achieved efficiently if coordination costs are reduced, IT can contribute to firm productivity by reducing coordination costs, thus facilitating a higher level of coordination. Production enhancement can also be achieved by IT applications that automate production processes and improve the capabilities of existing machinery. IT, however, is most often used to reduce coordination costs within and between organizations. Organizations can produce more if they cooperate, each specializing in its own productive activities and then interacting with one another to acquire the actual goods and services they desire (Milgrom and Roberts 1992). When organizations are specialized producers that need to trade, their decisions and actions need to be coordinated to achieve these gains. A key problem in achieving coordination is that the information needed to determine the best use of resources is not freely available. By providing better means of communication, information processing, and searching, IT reduces coordination costs, improves the coordination cost efficiency, and contributes to firm productivity.

The microeconomic theory of production considers the firm as a producer of goods and services. The production process requires a set of inputs—such as capital, labor, materials—in order to produce output. The theory of production assumes that a competitive firm will adopt the most productive bundle of inputs by substituting more productive inputs for less productive inputs. The most efficient economic output is produced by combining inputs in the most efficient manner over time. From this perspective, IT can be regarded as an input equivalent to capital, labor, or other production factors. As an input, IT contributes to an increase in firm output by improving the cost efficiencies of labor and capital. As mentioned above, productivity gains can be achieved by coordination cost efficiency, as well as production cost efficiency. Thus, coordination (costs) will be considered here as an important factor in the analysis of the impact of IT on firm productivity.

3. ECONOMETRIC APPROACH

The approach taken in this paper is to use an economy-wide United States firm-level dataset to examine directly the relationship between IT and coordination costs and the relationship between IT and firm productivity. Thus, the unit of analysis in this study is a firm. The data are divided into six sectors: durable goods manufacturing; non-durable
goods manufacturing; transport and utilities; wholesale and retail trade; finance, insurance, and real estate; and services. Several regressions are run on this data to identify the direction and magnitude of the relationship between IT and coordination costs, controlling for firm-specific factors, such as research and development (R&D), advertising activities, and industry and year effects. Other regressions are also run on the same data to identify the direction and magnitude of the relationship between IT and firm output, while controlling for coordination and other production factors that contribute to firm output. Following a microeconomic theory of production, production factors, such as total capital, labor, and R&D, in addition to coordination, are considered. A control for industry and year is also performed.

3.1 Data Sources and Variable Construction

Two data sources are used: (1) a dataset on IS spending by large U.S. firms compiled by International Data Group (IDG) and (2) the Compustat database, a database of historical financial statement information. The dataset on IS spending was collected annually in a survey of IS executives from Fortune 500 and other selected firms. IS spending data collected from 1988 to 1992 are used. The dataset includes data on the market value of central processors used by each firm (mainframes, minicomputers, and supercomputers), the total central IS budget, the percentage of the IS budget devoted to labor expenses, the number of PCs and terminals in use, and a variety of other financial and IT-related information.

The total central IS budget figure reported in the survey includes labor expenses, materials, purchased services and software, and capital spending for the central IS department. The total central IS budget is used as a measure of IT spending. The market value of central processors is not used as a measure of IT spending since it is narrowly defined and does not include significant costs that could be counted as IT spending, such as personal computers, communication networks, file servers, and software.

The Compustat database is used to obtain the data for total capital spending, labor expenses, R&D expenses, advertising expenses, total sales, the number of employees, and the data needed for constructing the measures for coordination costs and value-added. Selling and general administrative expenses are used to construct a measure of coordination costs. Selling expenses are referred to as “order-getting” and “order-filling” costs. They include such items as salaries and commissions of sales personnel, advertising, warehousing, customer service, and shipping. The first two items are examples of order-getting costs; the last three are order-filling costs. General administrative expenses include the costs of integrating the various activities of the organization. Examples of general administrative expenses are top executive salaries, legal fees, general accounting, and research and development (Hansen 1990). Since coordination costs include costs involved in managerial decision-making, accounting, planning, and control processes (coordination costs incurred in an organization), and the costs of searching and selecting suppliers, and negotiating and enforcing contracts (coordination costs incurred in a market), these costs must be included in selling and general administrative expenses, which are operating expenses (non-manufacturing expenses for the manufacturing firms and non-service expenses for the service firms).

Data are collected about the firms whose names match the firm names in the IDG data. The Compustat database provides the data for selling and general administrative expenses (the item name is selling, general, and administrative expenses). Since this item includes other expenses, which are not included in coordination costs such as expenses for R&D, advertising, software, bad debt, and pension and retirement, the data for such items are obtained in order to construct a measure of coordination costs. For manufacturing industries, a measure of coordination costs is constructed by subtracting expenses for advertising, R&D, software, bad debt, and pension and retirement from selling, general, and administrative expenses. According to the definition used here, such expenses are not included in coordination costs. For non-manufacturing industries whose R&D expenses are small, a measure of coordination
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costs is constructed by subtracting the expenses for advertising, bad debt, and pension and retirement from selling, general, and administrative expenses. For finance industries, a measure of coordination costs is constructed by subtracting only advertising expenses and pension and retirement expenses from selling, general, and administrative expenses since the other items are not applicable to the financial institutions.

Two measures of firm output are considered: (1) total firm sales and (2) value-added. Total firm sales can be obtained by taking total sales from the Compustat database. The value-added is defined as the value of the finished goods minus the value of raw materials and other suppliers. It is derived by subtracting the costs of raw materials from the value of production. The value of production is derived by subtracting the beginning inventory from the sum of the ending inventory and total sales. The Compustat database is also used to obtain the data for constructing the measure of value-added. The data are collected for the firms whose names match the firm names in the IDG data. Since the data on the costs of raw materials are not available from the data source, a measure is constructed for the costs of raw materials by subtracting labor and overhead expenses from the costs of goods sold. The data items obtained from the Compustat database to construct the value-added are as follows: total sales, the costs of goods sold, the ending inventory in finished goods and work-in-process, beginning inventory, labor and related expenses, depreciation and amortization, interest expenses, and rental expenses.

The series for all the variables used in the empirical analysis are also converted to constant 1987 dollars using appropriate deflators—an aggregate of deflators used to derive constant-dollar gross domestic product (GDP) estimates. Most are based on price indexes published in *Bureau of Economic Analysis* (1993) and *Economic Report of the President* (1994). By dividing each series of variables by its associated deflators, nominal values are converted into constant-dollar or real values.

In order to control for the industry- and year-specific effects, dummy variables are included for each industry or sector that is categorized by the standard industrial classification (SIC) code. Summary statistics for the sample are presented in Tables 1 and 2. The sample includes 540 observations over five years on approximately 232 different companies.

**Table 1. Inputs as a Percentage of Total Sales (Five Year Averages)**

<table>
<thead>
<tr>
<th></th>
<th>Manufacturing</th>
<th>Service</th>
<th>Full Sample with R&amp;D</th>
<th>Full Sample without R&amp;D</th>
</tr>
</thead>
<tbody>
<tr>
<td>IT (IS) Budget</td>
<td>2.13%</td>
<td>2.53%</td>
<td>2.25%</td>
<td>2.22%</td>
</tr>
<tr>
<td>Coordination Costs</td>
<td>10.98%</td>
<td>16.88%</td>
<td>11.81%</td>
<td>12.27%</td>
</tr>
<tr>
<td>SGA Expenses</td>
<td>16.68%</td>
<td>20.76%</td>
<td>17.56%</td>
<td>17.58%</td>
</tr>
<tr>
<td>Capital Spending</td>
<td>45.22%</td>
<td>54.19%</td>
<td>47.19%</td>
<td>47.19%</td>
</tr>
<tr>
<td>Labor Expenses</td>
<td>19.56%</td>
<td>17.84%</td>
<td>19.69%</td>
<td>19.19%</td>
</tr>
<tr>
<td>R&amp;D Expenses</td>
<td>2.27%</td>
<td>n/a</td>
<td>2.41%</td>
<td>n/a</td>
</tr>
<tr>
<td>Number of Firms</td>
<td>425</td>
<td>115</td>
<td>447</td>
<td>540</td>
</tr>
<tr>
<td>Average Firm Sales</td>
<td>$8,019 million</td>
<td>$8,335 million</td>
<td>$8,413 million</td>
<td>$8,086 million</td>
</tr>
</tbody>
</table>
According to transaction cost economics (Williamson 1975), high market transaction (external coordination) costs arise when transactions are supported by transaction-specific assets. Human assets are transaction-specific when new products and technologies are developed by a particular research team, and advertising is made by a particular advertising team.

### Table 2. Inputs as a Percentage of Value-Added (Five Year Averages)

<table>
<thead>
<tr>
<th></th>
<th>Manufacturing</th>
<th>Service</th>
<th>Full Sample with R&amp;D</th>
<th>Full Sample without R&amp;D</th>
</tr>
</thead>
<tbody>
<tr>
<td>IT (IS) Budget</td>
<td>3.67%</td>
<td>4.22%</td>
<td>3.84%</td>
<td>3.80%</td>
</tr>
<tr>
<td>Coordination Costs</td>
<td>17.91%</td>
<td>26.13%</td>
<td>18.76%</td>
<td>19.85%</td>
</tr>
<tr>
<td>SGA Expenses</td>
<td>27.13%</td>
<td>32.27%</td>
<td>27.91%</td>
<td>28.34%</td>
</tr>
<tr>
<td>Capital Spending</td>
<td>76.53%</td>
<td>77.14%</td>
<td>74.63%</td>
<td>76.67%</td>
</tr>
<tr>
<td>Labor Expenses</td>
<td>32.40%</td>
<td>27.13%</td>
<td>31.75%</td>
<td>31.15%</td>
</tr>
<tr>
<td>R&amp;D Expenses</td>
<td>3.81%</td>
<td>n/a</td>
<td>4.01%</td>
<td>n/a</td>
</tr>
<tr>
<td>Number of Firms</td>
<td>361</td>
<td>110</td>
<td>379</td>
<td>471</td>
</tr>
<tr>
<td>Average Firm Sales</td>
<td>$5,145 million</td>
<td>$5,210 million</td>
<td>$5,521 million</td>
<td>$5,160 million</td>
</tr>
</tbody>
</table>

### 3.2 Analysis of the Relationship Between IT and Coordination Costs

#### 3.2.1 Methodology

For analyzing the relationship between IT and coordination costs, an analysis of the combined dataset for all five years is performed. Two different techniques are used: an ordinary least-squares (OLS) regression and two-stage least-squares (TSLS) regression, while controlling for other explanatory variables such as advertising and R&D expenses. TSLS regression is used to correct potential biases caused by the simultaneity problem. Advertising expenses and R&D expenses are used as control variables because it is assumed that firms spending a large amount on R&D and advertising must be spending a large amount on coordination costs.¹

For controlling the firm-size effect, the firm size is adjusted by dividing coordination costs by total sales, and by dividing IT spending, advertising expenses, and R&D expenses by the number of employees. Since large organizations are likely to spend more money on IT and the coordination of economic activities, the relationship between IT spending per employee and coordination costs per total sales, that is, the coordination cost efficiency, is empirically examined. The error terms are also investigated by looking at the distribution of the residuals for each sector, and the research finds that the residuals for all the sectors are normally distributed. Thus, the data are not transformed.

#### 3.2.2 The Model

The model measures the relationship between the level of IT spending and coordination costs for a given sector in a given year, while controlling for R&D expenses, advertising expenses, and industry- and year-specific effects. The basic model is as follows:

¹According to transaction cost economics (Williamson 1975), high market transaction (external coordination) costs arise when transactions are supported by transaction-specific assets. Human assets are transaction-specific when new products and technologies are developed by a particular research team, and advertising is made by a particular advertising team.
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$$\text{COOR}_{it} = \beta_0 + \beta_1 \text{IT}_{it} + \beta_2 \text{R&D}_{it} + \beta_3 \text{AD}_{it} + \beta_4 \text{INDUSTRY}_{it} + \beta_5 \text{YEAR}_{it} + \epsilon$$

where

- $\text{COOR}_{it}$ = Coordination costs per total sales (the coordination cost efficiency) of the $i^{th}$ firm in year $t$
- $\text{IT}_{it}$ = IT spending per employee for the $i^{th}$ firm in year $t$
- $\text{R&D}_{it}$ = R&D expenditure per employee for the $i^{th}$ firm in year $t$
- $\text{AD}_{it}$ = Advertising expenses per employee for the $i^{th}$ firm in year $t$
- $\text{INDUSTRY}_{it}$ = A dummy for each sector or industry where the $i^{th}$ firm is operating in year $t$
- $\text{YEAR}_{it}$ = A dummy for year for the $i^{th}$ firm
- $\epsilon$ = An error term with zero mean

The model is estimated for the full sample both with and without R&D since the R&D variable is not applicable for most firms in sectors other than the manufacturing sector. The model is also estimated for each sector separately in order to see if the impact of IT differs across sectors.

The model for the relationship between IT and coordination costs basically tests a hypothesis: IT reduces coordination costs. According to this hypothesis, it is expected that the coefficient on IT spending in all of the equations will be negative. The coefficients of R&D expenses and advertising expenses are expected to be positive.

### 3.2.3 The Results and Discussion

From the analysis of the OLS regression, it was found that IT spending is strongly associated with a decline in coordination costs ($p < .01$) for the full sample and for each individual sector—except the transport and utilities sector (Table 3). The estimates are consistent with the hypothesis that IT reduces coordination costs. The t-statistics for the estimates of IT spending for the full sample both with and without R&D, the manufacturing, and the trade industry are 8.304, 6.819, 2.864, and 2.693 respectively. Thus the null hypothesis of zero effect of IT at the .01 (two-tailed) confidence level can be rejected for the full sample and for both individual industries. \(^2\) The estimate of IT spending for the transport and utilities sector is negative, as expected, but not significant. This may indicate that the effect of IT on coordination costs might be less significant in the transport and utilities sector than in the manufacturing and trade sectors. The sample size for the transport and utility industry, however, might affect the magnitude of the coefficient of IT spending. R&D expenses and advertising expenses also have significant positive relationships with coordination costs as expected ($p < .01$). The analysis using TSLS regression shows similar results (Table 4).

The results clearly show that IT spending is strongly associated with lower coordination costs. While the results suggest that a 1% increase in IT spending per employee is associated with .0085 % decrease in coordination costs per sales for the full sample with R&D, these results should only be used to draw conclusions about the direction of the impact, rather than the magnitude, since the measures used only capture some components of IT spending and coordination costs. Although these components can be expected to have a high correlation with overall costs, no implications about the magnitude of change should be drawn from the analysis.

The results imply that IT improves coordination cost efficiency and facilitates a higher level of coordination since IT reduces coordination costs for a given level of sales. Since coordination of economic activities can contribute to firm output, IT can contribute to firm output by improving coordination cost efficiency. Therefore, it is argued that

\(^2\)Muticollinearity is probably present in the analysis, but the estimates are still unbiased and statistically significant even though the possible presence of multicollinearity increases the standard errors of the estimates.
IT enhances firm productivity by improving both coordination cost efficiency and production cost efficiency such as capital and labor efficiency. In the following section, an empirical examination is done on the relationship between IT and firm productivity, considering coordination (costs) as a factor of production.

3.3 Analysis of the Relationship Between IT and Firm Productivity

3.3.1 Methodology and Model

For analyzing the combined data of cross section and time series, OLS and TSLS regression estimates of the correlation between IT and firm output are also used, while controlling for other explanatory variables, industry- and year-specific effects. The model is based on the microeconomic theory of production. The research employs IT spending as an input such as capital and labor. It also incorporates R&D expenses and coordination costs as input factors that might affect the level of output. Output is defined as the number of units produced times their unit value.

Productivity is defined as the ratio of the level of output to a given level of input. The Cobb-Douglas model for production specification is adopted since the Cobb-Douglas specification for the studies of IT productivity is widely supported in the literature (Brynjolfsson and Hitt 1993, 1996; Hitt and Brynjolfsson 1994; Lichtenberg 1995; Loveman 1994). The Cobb-Douglas specification for the model is as follows:

$$\text{OUTPUT} = e^{b_0} \cdot IT^{b_1} \cdot \text{CAPITAL}^{b_2} \cdot \text{LABOR}^{b_3} \cdot \text{R&D}^{b_4} \cdot \text{COOR}^{b_5}$$

Table 3. OLS Regressions: Dependent Variable—Coordination Costs/Sales

<table>
<thead>
<tr>
<th></th>
<th>Manufacturing</th>
<th>Transportation and Utilities</th>
<th>Trade</th>
<th>Full Sample</th>
<th>Full Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>IT/EMP</td>
<td>-.0036***</td>
<td>-.0031</td>
<td>-.0039***</td>
<td>-.0085***</td>
<td>-.0063***</td>
</tr>
<tr>
<td></td>
<td>(2.864) a</td>
<td>(1.319)</td>
<td>(2.693)</td>
<td>(8.304)</td>
<td>(6.819)</td>
</tr>
<tr>
<td>R&amp;D/EMP</td>
<td>.0052***</td>
<td>NA</td>
<td>NA</td>
<td>.0072***</td>
<td>Not Included</td>
</tr>
<tr>
<td></td>
<td>(4.774)</td>
<td></td>
<td></td>
<td>(8.248)</td>
<td></td>
</tr>
<tr>
<td>AD/EMP</td>
<td>.0013**</td>
<td>-.0039</td>
<td>.0334***</td>
<td>.0034***</td>
<td>.0040***</td>
</tr>
<tr>
<td></td>
<td>(2.032)</td>
<td>(.605)</td>
<td>(6.617)</td>
<td>(6.455)</td>
<td>(7.407)</td>
</tr>
<tr>
<td>Dummy</td>
<td>Industry and Year</td>
<td>Industry and Year</td>
<td>Industry and Year</td>
<td>Sector and Year</td>
<td>Sector and Year</td>
</tr>
<tr>
<td>R²</td>
<td>43.8%</td>
<td>62.8%</td>
<td>73.8%</td>
<td>28.8%</td>
<td>17.6%</td>
</tr>
<tr>
<td>N(total)</td>
<td>437</td>
<td>35</td>
<td>68</td>
<td>459</td>
<td>549</td>
</tr>
<tr>
<td>DW b</td>
<td>2.00</td>
<td>1.93</td>
<td>1.93</td>
<td>1.81</td>
<td>1.54</td>
</tr>
</tbody>
</table>

Key: ***(p<.01), ***(p<.05), *(p<.1)

a T Statistics in parentheses.

b If the Durbin Watson (DW) statistic is close to 2, it indicates no serial correlation. If the DW is greater than 2 or less than 2, it indicates high serial correlation. This suggests that the point estimates are correctly estimated but that the standard error estimates may be biased upward or downward.

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3 The amount of output that can be produced for a given unit of a given input is often measured as the marginal product of the input, which can be interpreted as a rate of return—increase in output per input (Berndt 1991; Brynjolfsson and Hitt 1996).
Impact of IT on Coordination Costs

The output elasticity of IT, \( E_{IT} \), is defined as:

\[
E_{IT} = \frac{M_{Output}}{M_{IT}} \left( \frac{IT}{Output} \right).
\]

From the production specification, this reduces to:

\[
E_{IT} = \frac{1}{\epsilon_{0}} \frac{e_{1}}{\epsilon_{1}} \frac{c_{2}}{\epsilon_{2}} \frac{c_{3}}{\epsilon_{3}} \frac{c_{4}}{\epsilon_{4}} \frac{c_{5}}{\epsilon_{5}} \left( \frac{IT}{e_{0}} \frac{e_{1}}{c_{1}} \frac{c_{2}}{c_{3}} \frac{c_{4}}{c_{5}} \right) = \frac{1}{\epsilon_{0}}
\]

The marginal product for IT is simply the output elasticity multiplied by the ratio of output to IT input (Brynjolfsson and Hitt 1996):

\[
MP_{IT} = \frac{\partial \text{Output}}{\partial IT} = E_{IT} \left( \frac{Output}{IT} \right)
\]

Table 4. TSLS Regressions\(^a\): Dependent Variable—Coordination Costs/Sales

<table>
<thead>
<tr>
<th></th>
<th>Manufacturing and Utilities</th>
<th>Trade</th>
<th>Full Sample</th>
<th>Full Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>IT/EMP</td>
<td>-.0040**</td>
<td>.0034</td>
<td>-.0090*</td>
<td>-.0092***</td>
</tr>
<tr>
<td></td>
<td>(2.061)(^b)</td>
<td>(.878)</td>
<td>(1.743)</td>
<td>(6.991)</td>
</tr>
<tr>
<td>R&amp;D/EMP</td>
<td>.0045***</td>
<td>N/A</td>
<td>N/A</td>
<td>.0069***</td>
</tr>
<tr>
<td></td>
<td>(3.195)</td>
<td></td>
<td></td>
<td>(6.272)</td>
</tr>
<tr>
<td>AD/EMP</td>
<td>.0017*</td>
<td>-.0018</td>
<td>.0257***</td>
<td>.0037***</td>
</tr>
<tr>
<td></td>
<td>(1.781)</td>
<td>(.204)</td>
<td>(3.201)</td>
<td>(5.113)</td>
</tr>
<tr>
<td>Dummy Industry and Year</td>
<td>Industry and Year</td>
<td>Industry and Year</td>
<td>Industry and Year</td>
<td></td>
</tr>
<tr>
<td>R(^b)</td>
<td>38.9%</td>
<td>52.0%</td>
<td>78.8%</td>
<td>26.7%</td>
</tr>
<tr>
<td>N(total)(^f)</td>
<td>272</td>
<td>23</td>
<td>36</td>
<td>287</td>
</tr>
</tbody>
</table>

Key: ***(p<.01), **(p<.05), *(p<.1)

\(^a\)Instrument variables: once lagged independent variables (IT spending, R&D, and AD).

\(^b\)T Statistics in the parentheses.

\(^f\)N(total) of TSLS is lower because each observation requires data for the current period and the previous period; this eliminates observations for all of 1988 and some in other years.

In this specification, \( \beta_1 \) and \( \beta_5 \) are the output elasticity of IT and coordination respectively. From the Cobb-Douglas specification, a model for a linear regression can be derived by taking the natural logarithm, including industry and year dummies, as follows:

\[
\ln\text{OUTPUT}_{it} = \beta_0 + \beta_1 \ln IT_{it} + \beta_2 \ln\text{CAPITAL}_{it} + \beta_3 \ln\text{LABOR}_{it} + \beta_4 \ln R&D_{it} + \beta_5 \ln\text{COORD}_{it} + \beta_6 \text{INDUSTRY}_{it} + \beta_7 \text{YEAR}_{it} + \epsilon
\]

where

\[
\begin{align*}
\ln\text{OUTPUT}_{it} &= \text{Total sales or value-added of the } i^{th} \text{ firm in year } t \\
\ln IT_{it} &= \text{IT spending of the } i^{th} \text{ firm in year } t \\
\ln\text{CAPITAL}_{it} &= \text{Total capital spending of the } i^{th} \text{ firm in year } t \\
\ln\text{LABOR}_{it} &= \text{Labor expenses of the } i^{th} \text{ firm in year } t \\
\ln R&D_{it} &= \text{R&D expenditure of the } i^{th} \text{ firm in year } t \\
\ln\text{COORD}_{it} &= \text{Coordination costs of the } i^{th} \text{ firm in year } t
\end{align*}
\]

\(^6\)The output elasticity of IT, \( E_{IT} \), is defined as: \( E_{IT} = (\partial \text{Output}/\partial IT) \) (IT/Output). From the production specification, this reduces to:

\[
E_{IT} = \beta_1 e^{\beta_1 IT^{\beta_1} \text{CAPITAL}^{\beta_2} \text{LABOR}^{\beta_3} R&D^{\beta_4} \text{COORD}^{\beta_5} (IT/\partial IT) \text{CAPITAL}^{\beta_2} \text{LABOR}^{\beta_3} R&D^{\beta_4} \text{COORD}^{\beta_5}) = \beta_1
\]

The marginal product for IT is simply the output elasticity multiplied by the ratio of output to IT input (Brynjolfsson and Hitt 1996):

\[
MP_{IT} = \frac{\partial \text{Output}}{\partial IT} = E_{IT} (\text{Output}/IT)
\]
Shin

\[
\text{INDUSTRY}_{it} = \text{A dummy for each sector or industry where the } i^{th} \text{ firm is operating in year } t
\]

\[
\text{YEAR}_{it} = \text{A dummy for year for the } i^{th} \text{ firm.}
\]

\[
\epsilon = \text{An error term with zero mean}
\]

The model is estimated for the full sample both with and without R&D since the R&D variable is not applicable for most firms in the service industry. The model is also estimated for both the manufacturing industry and service industry separately in order to see if the productivity impact of IT is different in these industries.

The model is also estimated after dividing all of the variables by the number of employees in order to examine the impact of IT spending per employee on output per employee since a firm can produce a higher level of output with a higher level of inputs. By using a different specification, the robustness of the results in the analysis is achieved. For further robustness, the model is also estimated without the natural logarithm of coordination costs by assuming that coordination costs are not a factor of production but still affect productivity.

3.3.2 The Results

From the analysis of the full sample, controlled for year-specific effects, the research found that IT spending is strongly associated with increases in both firm sales \((p < .01)\) (Table 5) and value-added \((p < .05)\) (Table 6). As shown in column 7 of Table 5, the estimate of IT spending indicates that the elasticity of output (sales) for IT spending is .1894 when all other inputs are held constant. Because IT spending accounts for average of 2.22% of the value of output each year, this implies that a gross marginal product for IT spending is approximately 853% per year.\(^5\) In other words, an additional dollar of IT spending is associated with an increase in output (sales) of 8.53 dollars per year on the margin. As expected, the estimate of coordination costs is positive and significant \((p < .01)\). The output elasticity for coordination is .0818. This implies that each dollar spent on coordination is associated with a marginal increase in output (sales) of 67 cents.

The above estimates are consistent with the hypotheses that the contributions of both IT and coordination are positive. The t-statistics for the estimates of the output (sales) elasticity of IT spending and coordination are 9.664 and 3.704 respectively (Column 7 of Table 5). Thus the null hypotheses of zero contributions of both IT and coordination can be rejected at the .01 (two-tailed) confidence level.

The results also show that capital spending and labor expenses are highly associated with an increase in firm output \((p < .01)\). Interestingly, R&D expenses are highly associated with an increase in value-added, but with a decline in firm sales. It was also found that the contribution of IT and coordination to firm output—both sales and value-added—are positive and significant in both industries (Tables 5 and 6). The signs of the estimates of other variables are also similar for both the manufacturing industry and service industry. However, R&D is strongly associated with an increase in value-added, but not with an increase in firm sales.

\(^5\)The earlier study done by Brynjolfsson and Hitt (1996) reported that the marginal product for IT was 81%. This study, however, uses IS budget (flow) as a measure of IT, compared to Brynjolfsson and Hitt’s study, which uses computer capital (stock) as a measure of IT. This makes a difference in the magnitude of the marginal product.
The results of the analysis without the natural logarithm of coordination costs are similar to the results of the analysis with the natural logarithm of coordination costs. IT spending, coordination costs, and other variables are strongly associated with increases in both firm sales ($p < .01$) and value-added ($p < .05$). The impacts of IT on firm output (both sales and value-added) are similar across both the manufacturing industry and service industry. Similarly, the coefficient of R&D is positive and significant for the analysis with value-added, but not for the analysis with firm sales. The results are shown in the even columns in Tables 5 and 6.

The analysis adjusting all the variables with the number of employees shows similar results. The results of the TSLS regression analysis are also comparable to the results of the above OLS regression analysis. The standard errors of the coefficient estimates of the independent variables are substantially larger since instrumental variables are used.

### Table 5. OLS Regression: Dependent Variable—LnSales

<table>
<thead>
<tr>
<th></th>
<th>Manufacturing</th>
<th>Service</th>
<th>Full Sample with R&amp;D</th>
<th>Full Sample without R&amp;D</th>
</tr>
</thead>
<tbody>
<tr>
<td>LnIT</td>
<td>.0780***</td>
<td>.0955***</td>
<td>.1489*** (7.993)</td>
<td>.1820*** (9.461)</td>
</tr>
<tr>
<td></td>
<td>(3.963)</td>
<td>(4.705)</td>
<td>(4.002)</td>
<td>(3.172)</td>
</tr>
<tr>
<td>LnCOOR</td>
<td>.1594*** (7.595)</td>
<td>.2871*** (3.478)</td>
<td>.1686*** (8.231)</td>
<td>.0818*** (3.704)</td>
</tr>
<tr>
<td>COOR</td>
<td>.00007*** (4.504)</td>
<td>.0001*** (5.241)</td>
<td>.0001*** (8.050)</td>
<td>.00008*** (5.835)</td>
</tr>
<tr>
<td>LnCAPITAL</td>
<td>.3507*** (12.830)</td>
<td>.3264*** (11.539)</td>
<td>.4119*** (23.226)</td>
<td>.3276*** (17.697)</td>
</tr>
<tr>
<td>LnLABOR</td>
<td>.3320*** (10.780)</td>
<td>.3918*** (12.880)</td>
<td>.2850*** (3.053)</td>
<td>.2621*** (8.861)</td>
</tr>
<tr>
<td>LnR&amp;D</td>
<td>.0087 (4.71)</td>
<td>.0315* (1.664)</td>
<td>N/A</td>
<td>-.0334** (2.279)</td>
</tr>
<tr>
<td>Dummy</td>
<td></td>
<td></td>
<td>Industry and Year</td>
<td>Industry and Year</td>
</tr>
<tr>
<td>R²</td>
<td>95.0%</td>
<td>94.6%</td>
<td>78.6%</td>
<td>81.3%</td>
</tr>
<tr>
<td>N(total)</td>
<td>425</td>
<td>115</td>
<td>447</td>
<td>540</td>
</tr>
<tr>
<td>DWb</td>
<td>2.11</td>
<td>2.06</td>
<td>2.03</td>
<td>1.95</td>
</tr>
</tbody>
</table>

Key: ***($p < .01$), **($p < .05$), *(p < .1)
T statistics in parentheses.

If the Durbin Watson (DW) statistic is close to 2, it indicates no serial correlation. If the DW is greater than 2 or less than 2, it indicates high serial correlation. This suggests that the point estimates are correctly estimated but that the standard error estimates may be biased upward or downward.

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The tables are available from the author upon request.

The tables are available from the author upon request.
In this paper, an empirical examination of the relationship between IT and coordination costs using the firm-level data was conducted. The results clearly show a significant negative relationship between IT spending and coordination costs for the five years from 1988 to 1992. These results strongly support the hypothesis that IT reduces coordination costs. By developing a measure for coordination costs, empirical evidence could be provided for supporting the theoretical speculation that IT reduces coordination costs.

An empirical examination of the relationship between IT and firm productivity using firm-level data was also conducted. The study tested a broad variety of specifications, based on both the microeconomic theory of production used by previous IS researchers as their theoretical basis, and the information processing theory of organization used by previous organizational researchers as their theoretical basis. The study also examined subsamples such as the manufacturing industry and the service industry. Overall, it was found that IT and coordination are highly associated with an increase in firm output.

### Table 6. OLS Regression: Dependent Variable—LnValue-Added

<table>
<thead>
<tr>
<th></th>
<th>Manufacturing</th>
<th>Service</th>
<th>Full Sample with R&amp;D</th>
<th>Full Sample without R&amp;D</th>
</tr>
</thead>
<tbody>
<tr>
<td>LnIT</td>
<td>.0103***</td>
<td>.0337**</td>
<td>.0504**</td>
<td>.0628***</td>
</tr>
<tr>
<td></td>
<td>(.815)</td>
<td>(2.531)</td>
<td>(2.655)</td>
<td></td>
</tr>
<tr>
<td>LnCOOR</td>
<td>.1780***</td>
<td>.2800**</td>
<td>.2800**</td>
<td>.2272***</td>
</tr>
<tr>
<td></td>
<td>(12.750)</td>
<td>(8.102)</td>
<td>(8.102)</td>
<td>(17.530)</td>
</tr>
<tr>
<td>COOR</td>
<td>.00008***</td>
<td>.00006***</td>
<td>.00006***</td>
<td>.00007***</td>
</tr>
<tr>
<td></td>
<td>(6.622)</td>
<td>(4.745)</td>
<td>(4.745)</td>
<td>(7.236)</td>
</tr>
<tr>
<td>LnCAPITAL</td>
<td>.2226***</td>
<td>.1906**</td>
<td>.1906**</td>
<td>.1720***</td>
</tr>
<tr>
<td></td>
<td>(12.227)</td>
<td>(9.277)</td>
<td>(9.277)</td>
<td>(5.004)</td>
</tr>
<tr>
<td>LnLABOR</td>
<td>.5230***</td>
<td>.5853**</td>
<td>.5853**</td>
<td>.4907***</td>
</tr>
<tr>
<td>LnR&amp;D</td>
<td>.0742***</td>
<td>.1072**</td>
<td>N/A</td>
<td>.0520***</td>
</tr>
<tr>
<td></td>
<td>(6.006)</td>
<td>(7.819)</td>
<td>N/A</td>
<td>(5.474)</td>
</tr>
<tr>
<td>Dummy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industry and Year</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R²</td>
<td>98.0%</td>
<td>97.4%</td>
<td>97.8%</td>
<td>97.0%</td>
</tr>
<tr>
<td>N(total)</td>
<td>361</td>
<td>110</td>
<td>379</td>
<td>471</td>
</tr>
<tr>
<td>DWb</td>
<td>2.09</td>
<td>2.07</td>
<td>2.43</td>
<td>2.59</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.77</td>
<td>1.85</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.79</td>
<td>1.81</td>
</tr>
</tbody>
</table>

Key: ***(p < .01), **(p < .05), *(p < .1)

T statistics in parentheses.

*If the Durbin Watson (DW) statistic is close to 2, it indicates no serial correlation. If the DW is greater than 2 or less than 2, it indicates high serial correlation. This suggests that the point estimates are correctly estimated but that the standard error estimates may be biased upward or downward.
The main contribution of this study is to provide a theoretical explanation and empirical evidence for how IT improves firm productivity, which has been incompletely addressed in the previous research on IT productivity gains. The study was done by focusing on one of the most salient features of IT: its reduction of coordination costs. The main argument is that IT reduces coordination costs for a given level of firm output and makes a higher level of coordination more efficient, thereby contributing to firm output. The empirical analysis of the relationship between IT and firm output is done by considering coordination (costs) as a factor of production in addition to capital spending, labor expenses, and R&D expenses. Based on the findings obtained from the analyses of the relationship between IT and coordination cost in section 3.2, and the relationship between IT and firm output in section 3.3, the study argues that IT contributes to firm output; that is, it improves firm productivity by enhancing the coordination cost efficiency. The results provide empirical evidence for strongly supporting the hypothesis that IT contributes to firm output by reducing coordination costs, thereby enhancing coordination cost efficiency.

5. REFERENCES


