INFORMATION TECHNOLOGY INVESTMENTS AND LABOR

Information Technology Investments and Labor Productivity

Abstract

Analyses of governmental data were reviewed to determine the relationship between information technology spending and labor productivity at the country and industry levels. Research studies were reviewed to determine the impact of computer technology on worker productivity. The analyses indicate that increased spending on computers and other types of information technology can increase labor productivity.

Introduction

Business owners and managers are often required to justify the cost of purchasing information technology. Information technology changes rapidly, and what was a state of the art computer one year ago is no longer on the cutting edge of technology. To remain competitive business owners and managers must make informed decisions about when and if the purchase of additional information technology or the upgrading of existing information technology will affect labor productivity and profitability.

Information technology generally includes a wide range of capital employed in business operations such as computers, telecommunications, software, and related services (Dedrick 2003). The majority of governmental statistics use this broad definition of information technology to track information technology spending at the country and industry levels. The majority of previous studies conducted by computer manufacturers and independent research labs to determine the affects of information technology spending on labor productivity have focused primarily on computer hardware.

Productivity is a measure of the effective use of business resources. Productivity can be calculated by dividing outputs by inputs. Inputs include such items as capital, materials, and labor. To increase productivity you must decrease inputs, increase outputs, or both (Farrell 2003). Labor productivity is the measurement of output per worker. Labor productivity growth refers to the measurement of increased output per worker (Dedrick 2003).

Labor productivity can be measured at the country, firm, industry, and worker levels. The measurement of labor productivity at the country and industry levels is primarily conducted by governmental agencies such as the Bureau of Labor Statistics. During the period from the early 1970's to the mid-1990's, the labor productivity growth rate of the United States declined

substantially from the 1960's. This decrease occurred at a time when there was a significant increase in information technology spending. This so-called "productivity paradox" has been the subject of substantial debate. Some economists believe that at the country level the paradox does not exist and that the correlation between labor productivity and information technology spending is not properly measured. Other economists believe that the paradox does exist and that increased spending on information technology has not increased labor productivity because investments in information technology are not properly managed.

This paper presents an analysis of the affects of increased information technology spending or capital deepening on labor productivity at the country and industry levels. The results of studies focused primarily on the affects of increased computer technology spending on worker productivity are reviewed. A discussion of the potential measurement problems associated with determining the affects of information technology spending on labor productivity is also presented. While some elements of this paper could be applied to all types of organizations, the focus of this paper is the correlation between labor productivity growth and information technology spending by business organizations. This coincides with the governmental measurements of labor productivity in the United States.

Information Technology Investment Decisions

Technological advances in information technology and computers can occur rapidly. Business managers and owners are frequently required to decide if more advanced computers will enhance their business by enabling them to hire fewer workers or by increasing worker productivity. Decisions must be made to determine if it is more effective to upgrade currently deployed computer systems or to purchase new computer systems.

The computer upgrade decision is often complex. The tasks performed within an organization by the aid of a computer can range from relatively simple data entry procedures to running complex computer aided design programs. If a business determines that an employee would be more productive using a newer computer system, the cost of a new computer system must be compared to labor productivity gains. The costs associated with maintaining older computer systems must also be considered. How older computer systems will interact with newer systems purchased for some employees but not others could result in adding a hidden cost to the purchase price of new computer systems.

A variety of resources exists to assist business managers and owners in making information technology purchase decisions. Analyses of governmental data, industry benchmark tests on computer systems, studies conducted by computer manufacturers and independent testing labs are some of the resources available to assist in making computer and other information technology purchases. This paper will present an analysis of these resources to assist business owners and managers with computer and other information technology decisions.

Labor Productivity and Information Technology

The labor-productivity growth rate in the United States has increased in recent years and is still increasing. According to the United States Bureau of Labor Statistics, the labor-productivity growth rate averaged 1.4% during the period 1973-1994 and averaged 2.4% during the period 1995-1999. More recently, the productivity growth rate in 2002 shot up to 4.8% (Farrell 2003).

The productivity growth related to investments in information technology is difficult to measure and it varies widely from industry to industry. During the past decade, information technology has grown from 2% of gross domestic product (GDP) in the United States to 12%.

Generally most businesses have substantially increased information technology spending during this period but just six business sectors: retailing, securities brokerage, wholesaling, semiconductors, computer assembly, and telecommunications have contributed to 76% of the labor productivity growth in the United States. These business sectors account for only 32% of total GDP in the United States. Many other business sectors such as television broadcasting and hotels invested heavily in information technology during the past decade but did not experience significant labor productivity growth (Farrell 2003). What would cause only some business sectors to experience labor productivity growth during a time when most business sectors have substantially increased information technology spending? The most likely answer is increasing competition in some business sectors. Managers in business sectors where there is fierce competition were forced to implement product-boosting innovations to remain competitive (Farrell 2003). Information technology spending coupled with efficient business practices and the effective use of purchased information technology all contributed to labor productivity gains in the business sectors that accounted for 76% of all labor productivity gains during the last decade.

Labor productivity is defined by some economists as output per hour and generally, three factors can increase labor productivity growth. First, labor productivity growth rises over time because of the employment of more sophisticated capital. Machines that are more efficient are used in today's manufacturing environment. Second, labor productivity rises over time because of the increased skills and knowledge of workers. Finally, labor productivity will increase due to new processes and innovations. This is often referred to as total factor productivity and is generally used to explain productivity growth not otherwise identified (Fernald 2003).

According to the Council of Economic Advisors, labor productivity grew at an average annual rate of 1.73% during the period 1995 through 2002. Investments in information technology accounted for 0.40% (or 23.12%) of the total 1.73% increase in labor productivity realized during this period. The main contributory factor to this labor productivity growth was an increase in information technology capital employed by businesses. This resulted primarily from the dramatic decrease in the cost of computer and other information technology per worker during the period.

The Productivity Paradox

Studies to determine the correlation between information technology spending and labor productivity where first conducted in the 1980's. These studies showed no relationship between information technology investments and labor productivity. During the past decade, multiple studies have been conducted at the industry and country levels that indicate a strong relationship between increased information technology spending and increased labor productivity growth (Derrick 2003).

Productivity may be easy to define but is it notoriously difficult to measure (Spithoven 2003). Studies conducted in the 1980's used inadequate data and small sample sizes (Dedrick 2003). This led to findings of a weak or nonexistent correlation between information technology spending and labor productivity growth. Beginning in the mid-1990's studies were conducted that used information technology investment data from market research firms, financial executives and other reliable sources.

Other recent studies have focused on the mathematical formulas employed to calculate the effects of information technology investments on labor productivity growth. Computers and other types of information technology generally have shorter life cycles than other classifications

of capital employed by businesses. The formulas used to compute the cost of information technology investments may be flawed. The technological obsolescence of information technology may not be properly accounted for in the formulas used to calculate labor productivity growth. Computers are often replaced with more advanced models before they are obsolete. Replaced computers are often used by businesses as backups (Whelan 2000). Inadequately addressing employee training and information technology implementation costs may also result in flawed calculations of labor productivity growth (Spithoven 2003). The life cycles of employee training and computer infrastructure costs are longer than the life cycle of computer hardware investments. These factors are not considered in the formulas utilized to calculate labor productivity growth. This results in an overstatement of the input costs used to calculate labor productivity.

Some economists look beyond the construction of the formulas employed to calculate labor productivity growth and believe that the productivity paradox resulting from studies in the 1980's is an anomaly. Information technology spending during the 1970's and early 1980's was simply too small of a component of GDP to measure the affects of information technology spending on a national basis.

Other economists believe that the productivity paradox does indeed exist and that the lack of correlation between increased information technology investing and labor productivity is largely due to management and organizational problems. Labor productivity gains were most prevalent when information technology spending was targeted at the most critical areas of a business. Careful attention must be given to the timing and type of information technology invested in. Information technology purchases made in isolation and not coordinated with other managerial innovations will most likely not result in labor productivity gains (Farrell 2003).

Organizational design and worker information overload may also contribute to the productivity paradox (Spithoven 2003). Managers must organize their business to be in line with the capabilities of information technology and change the role of employees to effectively use information technology investments. Information technology investments that are not coordinated with adequate employee training may not result in the expected increase in labor productivity.

Whether or not the productivity paradox exists will continue to be a topic of substantial debate. Inconsistencies in the formulas and data employed to calculate labor productivity growth have contributed to the debate. Rapid advancements in information technology may make the comparison of information technology investing over several decades difficult. Inadequate management practices and organizational design may also place constraints on labor productivity gains recognized by increased spending in information technology.

Worker Productivity Studies

Various studies have been conducted by independent research organizations and computer manufacturers to determine the affect of computer technology investments on worker productivity. The studies examine the effects of specific elements of a computer (such as a computer processor) and bundled computer systems on worker productivity. This paper reports on three recent studies.

Intel Study. The Information Technology Division at Intel Corporation conducted a study in 2002 to determine the labor productivity gains that could be derived by upgrading a worker's entire computer system. The study was conducted in Intel's Human Factors Engineering Usability labs using a cross-section of company employees. This study primarily resulted from

the increased demands from Intel customers for data comparing the business value of various computer systems.

Two computer systems were selected for the study. The first system contained a Pentium III computer processor, used the Microsoft Windows 2000 operating system, and included the Microsoft Office 2000 software bundle. The second system contained a Pentium 4 computer processor, used the Microsoft Windows XP operating system, and included the Microsoft Office XP software bundle.

Forty-five employees were selected at random from five different segments of Intel's business: project and people management, technical support, administrative assistants, design engineering and programming, and general office. The participants completed a PC skills assessment questionnaire, 75% of the participants considered themselves experienced computer users, and the remaining 25% considered themselves self-sufficient in computer use.

The employees were instructed to perform various computer tasks such as file searching, emailing attachments, opening documents using Windows Explorer, and copying and pasting information from Microsoft Excel to Microsoft Word. The participants would perform the set of computer tasks on each of the two systems used in the study. The order of the tasks the participants were required to perform on each system was not changed but the first system used by each participant was varied. This was intended to eliminate the influence of any "learning affects" that may be present because each participant performed the same tasks twice.

The same computer tasks assigned to the participants involved in the study were performed automatically by computer programs running on both systems. This enabled the assessment of only computer hardware and software performance by eliminating any possible human performance variables.

Tasks not completed successfully by participants on both computer systems were eliminated from the analysis of the testing results. The results of the study concluded that a 3% worker productivity gain was recognized when employees performed the tasks on the more technologically advanced Pentium IV computer system loaded with the most recent Microsoft Office software bundle. The results of the automated tests were similar. The computer system using the Pentium 4 processor and Microsoft Office XP software bundle executed the series of tasks in 82.19 seconds and the computer system using the Pentium III processor and Microsoft Office 2000 software bundle executed the series of tasks in 143.41 seconds.

The Intel Corporation translated the results of their study into an annual labor cost savings per employee. A 3% increase in worker productivity was associated with an annual labor cost savings of approximately $3,000 per Intel employee. This savings was substantially more than the cost of the computer systems used in the study.

Idea Group, Inc. – study one. The Idea Group, Inc. (Idea Group) is an independent computer-testing lab that conducted a study to determine the affects of computer processor speed on worker productivity. There is a general problem measuring the effects that computer technology investments have on worker productivity because information technology is integrated with so many elements of a business (Wierschem 2003). The Idea Group study was designed to isolate the effects of only processor speed on worker productivity.

The study was conducted using Pentium 133 and Pentium 200 computer systems. The hardware and software configurations on both systems were identical as was the operating system utilized by each system. Basic applications such as Microsoft Word and Microsoft Excel were loaded on each system.

The study was conducted in the computer labs of a college. The participants were selected at random from students enrolled in the college's Management Information Systems (MIS) program. All students selected had completed at least an introductory computer course and were familiar with the software programs and computers used in the study. To ensure quality control cooperative professors at the college required the students selected to participate as part of their course requirements.

Two separate computer skills assessment tests were constructed to use in the study. The tests consisted of basis operations that could be performed in Windows Explorer, Microsoft Word, and Microsoft Excel. Both tests were identical except for minor differences in the specifics of each question. For example, each test required the participants to find a particular file located on their computer system and only the file name on each test was different.

Each participant was required to complete both tests. Some participants used a Pentium 133 computer to complete one test and a Pentium 200 computer to complete the second test. Other participants were assigned a Pentium 133 computer or a Pentium 200 computer to complete both tests. Short-term learning affects could be isolated by requiring some students to take both tests using the same computer system.

The results of the testing were based upon the number of correct questions completed and the number of questions attempted. The tests were of sufficient length to ensure that no participant would complete the test on either computer system. This was done to eliminate the possibility of participants having time to review their answers after they completed their exam. The results of the testing concluded that a direct productivity gain of 4.4% was recognized when participants completed the tests on a Pentium 200 computer.

Idea Group, Inc. – study two. A study was conducted to determine the affects of computer system performance on employee productivity in a traditional office setting and to determine if user perception of computer system performance is an adequate measure for making computer upgrade decisions. SYSmarkNT, an industry-standard benchmark, was used to rate the performance of each computer system selected for the study because hardware configurations can affect computer performance. This standardized performance score was assigned to each system used in the study to facilitate interpretation of the results.

The study was conducted using computer systems with three different computer processors: Pentium 133, Celeron 266, and Pentium II 400. Each system utilized the Windows NT 4.0 operating system and Microsoft Word, Microsoft Excel and Microsoft PowerPoint programs were installed on each computer. All of the systems had the same model of 15-inch monitor, mouse, and keyboard.

One hundred seventy-five workers from temporary employment agencies were recruited by several universities to participate in the research. The research was conducted in the computer labs of the universities. Temporary employees were used in the study because they were accustomed to working in an organization for only a short period. Regular employees assigned work duties outside their typical responsibilities may develop the perception that the entire experience was artificial.

All temporary employees participating in the study had a minimum of six weeks experience and were screened using the Qwiz skills assessment test. All participants received their normal hourly pay plus incentive bonuses of up to fifty percent based on the quantity and quality of work performed. Only participants with an error rate of 2% or less would be eligible to receive an incentive bonus.

Twenty-one computer tasks were developed and were to be performed using the Excel, Word, and PowerPoint programs. The tasks involved creating new documents and modifying existing documents. The tasks used in the study were reviewed by temporary employment agencies to ensure the work assigned to the participants in the study was similar to their normal work assignments. Participants were free to complete the tasks in any manner they deemed appropriate.

The computer labs utilized in the research were arranged to create a realistic work environment. Workspace size was varied to simulate conditions normally experienced by temporary employees. Radios, conversations, and ringing telephones were also introduced into the workspace to simulate common distractions encountered by temporary employees.

The study used Platinum Technology's DeskWatch software to record each keystroke, mouse event, function call, and various other computer actions performed by each participant during the study. The data collected from participants who left early or who did not follow instructions was removed from the final analysis. The study concluded that participants using a Pentium II 400 computer system completed more complicated tasks in Microsoft Excel 10% faster than the participants using a Pentium 133 computer system did. Lower demand tasks that were performed mainly using Word and PowerPoint did not result in a significant increase in user productivity. The data collected using the DeskWatch software revealed that most of the productivity gains were the result of a decrease in the time it took participants to navigate the various programs.

Supervisors interviewed each employee at the end of the day to determine their opinion of the computer system assigned to them for the day. Participants did not know the type of computer system assigned to them during the study. At the time the study was conducted, the

Pentium 133 and Celeron 266 computer systems were the most likely systems to be used by temporary employees in a realistic office setting. Participants who traditionally used Pentium 133 or Celeron 266 computer systems at work had neutral to slightly negative opinions about the computer system they used during the study. Participants who used the Pentium II 400 computer system in the study had generally positive opinions about the system assigned to them. Based on this information, it was concluded that user perceptions of computer systems is not an effective measure when assessing computer upgrade needs.

Conclusion

Appropriate information technology purchasing decisions are critical to the profitability and long-term success of a business. Technology decisions are often complex because information technology is usually intertwined with multiple processes of a business. The total cost of ownership must be considered when making information technology purchasing decisions (Hogan 2003).

The speed of a computer processor or the benchmark testing results of a computer system cannot be the only factors that are considered when making computer purchase decisions. Human factors, the nature of work to be performed by workers using a computer, hardware and software compatibility issues, deployment costs, worker training, and organizational changes should be considered when making computer and other information technology purchase decisions.

Labor productivity may not increase immediately due to the purchase of information technology. Labor productivity gains may not be concurrent with the purchase of information technology because of required employee training, information technology infrastructure changes, and organizational changes that may accompany the purchase of information

technology. The implementation of new information technologies or the upgrading of existing information technologies must be part of an overall business plan.

Human factors can affect worker productivity derived from using computers. Worker productivity gains are more likely to be recognized when computer tasks are complex or the software used by employees requires substantial computer system resources. The productivity of workers performing simple tasks on a computer such as data entry will less likely be affected by the speed of a computer system. Due to human constraints, the amount of data that can be entered into a computer on any given day by a worker is limited. The purchase of more advanced computer systems may have no impact on the productivity of data entry and other lower level workers if the generation of computers currently being used is adequate.

Software compatibility should also be considered when implementing information technologies. The overall cost of implementing a new computer system may increase dramatically if previously licensed software programs are not compatible with newly purchased hardware. In contrast, newly purchased computer software programs may not run on previous generations of computer technology.

Hardware compatibility issues can also affect the overall cost of information technology implementation. A survey should be conducted to determine if older computer peripherals will operate effectively on new computer systems. Conversely, new computer peripherals may not function properly on older generations of computer systems.

Ongoing information technology maintenance costs should be considered when upgrading information technology. The time spent on maintaining an information technology infrastructure may increase if different generations of hardware and different versions of software are used by an organization. A computer may not be obsolete but the long-term cost of

maintaining multiple computer platforms may out weigh the short-term savings of implementing new computers on a piece-meal basis.

Organizational structures may need to change to accommodate new information technology purchases. Computers may replace task previously performed by workers. Decisions as to the disposition of these employees may need to be made. Additional computer personnel may be required to monitor and maintain the effectiveness of newly acquired systems.

Many factors enter into the decision of purchasing information technology. Under the right circumstances computer and other information technology purchases can increase labor productivity. Labor productivity gains must be weighed against the total cost of implementing new information technology. Information technology purchases cannot be made in a vacuum. An increase in labor productivity and ultimately an increase in business profits may not be recognized if the implementation of new information technology is not properly planned for and managed.

Information technology should be viewed as a tool to increase labor productivity and business profits. Computers and other categories of information technology should not be viewed as a replacement for managerial knowledge and innovation. To remain competitive managers and business owners must integrate information technology purchases with an overall business plan.

The analyses of economic data compiled by governmental agencies and recent studies conducted by computer manufacturers and independent test labs support the theory that labor productivity can be increased by properly utilizing information technology. The analyses of economic data included labor productivity at the country and industry levels. Recent computer studies have focused on labor productivity at the worker level. Additional research that

evidences the relationship of labor productivity and information technology at the firm level may prove useful in gaining a better understanding of the relationship between labor productivity and investments in information technology.

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