Information Technologies and Organizational Practices
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Some studies have attempted to measure organizational complements directly, and to show either that they are correlated with IT investment, or that firms that combine complementary factors have better economic performance. The correlations among IT, human capital and workplace organization found by Bresnahan, Brynjolfsson and Hitt (2000) are consistent with the view that all three are complements or that the same underlying causes or coincidences drive all three.

Finding correlations between IT and organizational change, or between these factors and measures of economic performance, is not sufficient to prove that these practices are complements, unless a full structural model specifies the production relationships and demand drivers for each factor (Brynjolfsson and Hitt, 2000). Athey and Stern (1997) discuss issues in the empirical assessment of complementarity relationships. However, after empirically evaluating possible alternative explanations and combining correlations with performance analyses, complementarities are often the most plausible explanation for observed relationships between IT, organizational factors, and economic performance.

The first set of studies on this area focuses on correlation between the use of IT and the extent of organizational change. An important finding is that IT investment is greater in organizations that are decentralized and have a greater level of demand for human capital. For example, Bresnahan, Brynjolfsson and Hitt (2000) surveyed approximately 400 large firms to obtain information on aspects of organizational structure like allocation of decision rights, workforce composition, and investments in human capital. They found that greater levels of IT are associated with increased delegation of authority to individuals and teams, greater levels of skills and education in the workforce, and greater emphasis on pre-employment screening for education and training. In addition, they found that these work practices are correlated with each other, suggesting that they are part of a complementary work system (Brynjolfsson and Hitt, 2000).

Research on jobs within specific industries has begun to explore the mechanisms within organizations that create these complementarities. Drawing on a case study on the automobile repair industry, Levy, Beamish, Murnane and Autor (2000) argue that computers are most likely to substitute for jobs that rely on rule-based decision making while complementing non-procedural cognitive tasks. In banking, researchers have found that many of the skill, wage and other organizational effects of computers depend on the extent to which firms couple computer investment with organizational redesign and other managerial decisions (Hunter, Bernhadt, Hughes and Skuratowitz, 2000; Murnane, Levy and Autor, 1999). Researchers focusing at the establishment level have also found complementarities between existing technology infrastructure and firm work practices to be a key determinant of the firm's ability to incorporate new technologies (Bresnahan and Greenstein, 1997); this also suggests a pattern of mutual causation between computer investment and organization.

A variety of industry-level studies also show a strong connection between investment in high technology equipment and the demand for skilled, educated workers (Berndt, Morrison and Rosenblum, 1992; Berman, Bound and Griliches, 1994; Autor, Katz and Krueger, 1998). Specifically, it is argued that many of these new technologies increase the demand for skilled workers. This skill-biased technical change hypothesis is offered as the primary explanation for the increased returns to education and the increased wage differential between skilled and unskilled workers recently in the United States (Doms, Dunne and Troske, 1997),

The possibility that skill-biased technical change is the cause of increased wage dispersion has led to a number of studies using industry, worker, and employer data, which examine whether technological change in the United States is in fact skill-biased. Berndt, Morrison, and Rosenblum (1992), Berman, Bound and Griliches (1994), and Autor, Katz, and Krueger (1996) all model changes in workforce skills as a function of changes in industry capital intensity and industry-level investment in computer equipment. All of these studies find evidence of capital skill complementarity and a strong positive correlation between the level of computer investment in an industry and changes in the skill of workers in the industry. Krueger (1993) and Autor, Katz, and Krueger (1996) use worker data to look at the correlation between wages and computer use by workers, and both studies find a strong positive correlation. Dunner and Schmitz (1995) and Siegel (1995) use plant-level data to show that plants that use more factory automation technologies employ more highly paid workers. These findings are consistent with the idea that increasing use of computers is associated with a greater demand for human capital.

Doms, Dunne and Troske (1997) performed a more recent study on workers, wages, and technology. The strength of their study relies on the fact that they used both, a cross-sectional data set as well as plant-level panel data.

The cross-sectional results are consistent with the view that "high tech" plants—those using a larger number of technologies--- employ more skilled workers. In particular, they found that a high proportion of college-educated workers are employed in technologically advanced plants. The positive correlation between the education of workers and technology use is found for both production and non-production workers

Doms, Dunne and Troske (1997) also found that the fraction of workers employed in scientific, engineering, managerial, and precision-craft occupations increases with the use of new technology. In addition, they found that technologically advanced plants employ more high wage production and technical/clerical/sales workers. These results are valid for plants that are much larger than average (averaging 961 employees).

Similarly, Bresnahan, Brynjolfsson and Hitt (2000) found that firms that have fewer high-school educated workers and/or more college-educated ones tend to have more IT. Firms which employ more managers and especially professionals are more likely to have high levels of IT, while those with more blue collar workers tend to have less IT.

In contrast, the time-series results from Doms, Dunne and Troske (1997) show little correlation between changes in workforce characteristics and their measures of technology adoption. Plants that adopt a large number of new technologies do not appear to increase their relative share of non-production labor or high-wage workers compared with plants that adopt a small number of new technologies. However, they found that plants that adopt a large (small) number of new technologies employ high (low) wage workers both prior to and post-adoption.

Their study suggests that, at the plant level, the correlation between technology use and worker wages is primarily due to the fact that plants with high wage workforces are more likely to adopt new technologies. Their findings that the adoption of new factory automation technologies is uncorrelated with plant-level changes in workforce skills stands up in sharp contrast to the strong positive correlation between changes in workforce skill and computer investment found in industry-level studies (e.g. Berndt, Morrison, and Rosenblum (1992), Berman, Bound, and Griliches (1994), Autor, Katz, and Krueger (1996)).

Doms, Dunne and Troske (1997) findings suggest that plants that adopt a large number of new technologies have more skilled workers both pre- and post-adoption. If they had examined only the cross-sectional data, they would have concluded that the most technologically advanced plants pay their workers 8-20 percent higher wages than the least technologically advanced plants. However, the time-series analysis shows that the most technologically advanced plants paid their workers higher wages prior to adopting new technologies. These results suggest that the commonly observed cross-sectional correlation between technology use and worker wages may be due to time-invariant unobserved workers quality differences.

It is important to emphasize that the types of technologies that Doms, Dunne, and Troske (1997) studied are quite distinct from computing equipment. The technologies that Doms, Dunne, and Troske (1997) examined are directly used in the production of manufacturing goods, whereas computing equipment is often a main tool of managerial and clerical labor. The technologies they examined are primarily used in the design and fabrication of products and the control of machinery and information on the factory floor. These technologies include: computer-aided design (CAD), CAD-controlled machines, digital CAD, flexible manufacturing systems/cell, numerically controlled machines/computer controlled machines, materials working lasers, pick/place robots, other robots, automatic storage/retrieval systems, technical data network, automated guided vehicle systems, factory network, intercompany computer network, programmable controllers, computers used in factory floor, and automated sensors.

When Doms, Dunne, and Troske (1997) included a plant-level measure of computer investment into their analysis, they found results similar to the industry-level studies—plants that invest relatively more in computing equipment have larger increases in the share of non-production labor. They concluded that the effect of new technologies on workforce structure depends critically on the type of technology being adopted. For the sample of plants they studied, it appears that the adoption of factory automation technologies is less correlated with skill upgrading than investment in new computing equipment.

Kelley (1994) analyzed the transition from conventional to programmable automation manufacturing technologies and its impact on the division of labor. She states that the transition from conventional to programmable automation machines involves changes in the skill content of production jobs. Craft skills important to conventional machine tool operation are made obsolete. New skills in programming are needed. Management has a choice as to where in the occupational hierarchy at the plant to locate programming tasks. These responsibilities can be performed by engineers or managers, or they can be "added" to the machine operator's job to replace the loss of skill associated with automation. Adopting a new design approach that gives production workers a high degree of autonomy in performing programming functions not only enriches their jobs, adds skills (and presumably increases employee satisfaction with their work), but the results of her study show that such a skill-upgrading approach to job re-design also provides a significant efficiency advantage to the firm. Plants in which all of the programmable automation machine operators routinely perform program editing and writing tasks are 30 percent more efficient compared to plants in which no production workers have these responsibilities.

Several researchers have also considered the effect of IT on macro-organizational structures. They have typically found that greater levels of investment in IT are associated with smaller firms and less vertical integration. Brynjolfsson, Malone, Gurbazani and Kambil (1994) found that increases in the level of IT capital in an economic sector were associated with a decline in average firm size in that sector, consistent with IT leading to a reduction in vertical integration. Hitt (1999), examining the relationship between a firm's IT capital stock and direct measures of its vertical integration, arrived at similar conclusions. These results corroborate earlier case analyses and theoretical arguments that suggested that IT would be associated with a decrease in vertical integration because it lowers the costs of coordinating externally with suppliers (Malone, Yates and Benjamin, 1987; Gurbaxani and Whang, 1991; Clemons and Row, 1992).

One difficulty in interpreting the literature on correlations between IT and organizational change is that some managers may be predisposed to try every new idea and some managers may be averse to trying anything new at all. In such a world, IT and "modern" work organization might be correlated in firms because of the temperament of management, not because they are economic complements. To rule out this sort of spurious correlation, it is useful to bring measures of productivity and economic performance into the analysis. If combining IT and organizational restructuring is economically justified, then firms that adopt these practices as a system should outperform those that fail to combine IT investment with appropriate organizational structures (Brynjolfsson and Hitt, 2000).

In fact, firms that adopt decentralized organizational structures and work structures do appear to have a higher contribution of IT to productivity (Bresnahan, Brynjolfsson and Hitt, 2000). For example, for firms that are more decentralized than the median firm (as measured by individual organizational practices and by an index of such practices), have, on average, a 13 percent greater IT elasticity and a 10 percent greater investment in IT than the median firm. Firms that are in the top half of both IT investment and decentralization are on average 5 percent more productive than firms that are above average only in IT investment or only the decentralized organization. It will be interesting to find out whether these findings are applicable to manufacturing organizations.

As of 1987, this did not seem to be the case according to the study performed by Maryellen Kelley (1994). She found that one source of efficiency advantage derives from the application of a bureaucratic system of control that depends on a high degree of standardization of work methods, and the use of specialists to develop those standards. Only about 15 percent of all manufacturing establishments had (1987) such a highly developed system of bureaucratic control. Employee participation mechanism should be advantageous if only as a means to update plant-wide procedures by incorporating what is learned from the more efficient practices developed by production workers through their control over the technical aspects of programming (Kelley, 1994).

However, as of 1987, plants that have introduced new institutional arrangements for promoting collaborative problem solving between managers and workers do not demonstrate a superior efficiency advantage over plants that rely on unions, the traditional mechanism for collective bargaining approach to problem-solving, or that use informal means to resolve problems. To attain the greatest efficiency, new work systems will need to be devised that retain the advantage from standardization associated with a bureaucratic system of control, while still providing the opportunity for production workers to exercise discretion in programming the new technology (Kelley, 1994).

Bresnahan, Brynjolfsson and Hitt (2000) found the following results when economic performance is measured as stock market valuation. Firms in the top third of decentralization have a 6 percent higher market value after controlling for all other measured assets; this is consistent with the theory that organizational decentralization behaves like an intangible asset. Moreover, the stock market value of a dollar of IT capital is between $2 and $5 greater in decentralized firms than in centralized firms (per standard deviation of the decentralization measure). This relationship is particularly striking for firms that are simultaneously extensive users of IT and highly decentralized (Brynjolfsson, Hitt and Yang, 2000). The weight of the firm-level evidence shows that a combination of investment in technology and changes in organizations and work practices facilitated by these technologies contributes to firm’s productivity growth and market value.

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