CHARTING THE IMPACTS OF INFORMATION TECHNOLOGY

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We have been asked in this session to examine what existing studies of the impacts of information technologies can tell us about techniques for assessing the outcomes of research. My paper provides an informal overview of some key features of that vast terrain.

My purpose is to identify some general features that apply across a range of disciplines, rather than to detail specific constructs that have appeared in studies of information technologies in the innumerable special settings that comprise much of the relevant literature. My characterization of general features represents my initial musings aimed at eventual construction of an integrated overview, rather than the paradigm of any one discipline. My use of words embraces the flexibility and plasticity of common English language, rather than the technical specifications of any one field.[2]

In the sections below, I consider the challenge of assessing the impacts of information technologies, strategies for building a tractable model, and kinds of impacts that have been studied. The concluding section of my paper suggests possible next steps.

I. COPING WITH CHALLENGE

"Information Technologies" (IT, including technologies for data storage and retrieval, computing, and communications) are transforming our economy, our society, and our lives. Research to assess impacts, though extensive, is still in the developmental stages. The methodological challenge for assessing the linkages among research in computer science and engineering and the eventual impacts of IT is the same as for other fields of science and technology.

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[2] For example, the paper does not attempt to untangle the distinctions among "outputs," "outcomes," and "impacts" of government programs made in the program evaluation literature.

Long Lags. There can be long lags before research results are put to use.

Unanticipated Applications. Eventual applications and impacts may not be foreseen at the time of the research.

Role of Unrelated Work. Independent developments in other fields may be required before applications become apparent or feasible. Today, for example, we know that Alan Turing's theoretical insights laid the groundwork for the explosion in applications of IT. But these applications were not possible until the semi-conductor was developed with other ends in mind.

Necessary But Not Sufficient. The practical application of research results is contingent on the separate actions of the many "handlers" of the knowledge, the forms in which the knowledge is "stored" (e.g., embedded in journals, in software, in manuals, in central data bases, in equipment, in human know-how), and the presence of an inter-connected set of social and institutional enabling conditions. For example, the prerequisites for bringing IT to the classroom include strategic understanding of the technology; funding for equipment, teacher training, and school hook-up; and commitment and participation of institutional staff, families, and the larger community.

Changing Institutional Frameworks. The economic and social institutions which condition the impact of IT are themselves transformed as they co-evolve with the new technologies.

II. MODELING INTERCONNECTIONS

Modeling the interconnections among research in computer science and engineering, the development and application of new technologies, the transformations of social and economic institutions, and the impacts of IT would require specification of a vast, interlocking, simultaneously-determined set of relationships. Estimation of the full model would require an enormous amount of data. Understanding the entire system would require far more empirical evidence than we now have.

Faced with the vastness and complexity of IT's permeation of society and the economy, individual researchers slice off tractable segments for separate study. Each study provides an additional chip for filling out the larger mosaic.

The rapid pace of change and the great diversity among the kinds of IT, the actors who handle and apply IT, and the settings in which IT are utilized mean that different models are needed to capture different dimensions of the larger tableau. A range of research models are in use, including those drawn from the social, behavioral, and economic sciences; computer science and engineering;

business administration; education; and the humanities. The decision about what model to use and what impacts to study is driven by the questions being addressed and the context for the inquiry.

III. CAPTURING IMPACTS

Impacts of IT on Uses of Information Technology. Humans have used some form of information technology for millennia prior to the introduction of today's "chip-based" technologies. Studies of the effects of the evolving chip-based technologies on human uses of information technology have revealed a broad range of direct effects. These are intertwined with diverse impacts widely dispersed among human activities and institutions.

Impacts of Research Programs. For program evaluation studies in computer science and engineering, as in other fields, analysts have tracked key technical developments that spurred significant technological innovations, and they have traced the role played by Federal support. They have also developed cost-benefit estimates for research results that subsequently led to specific technical advances.

Impacts of Research on Research. As in other fields, analysts have used citation studies to track linkages among research activities, including linkages between Federal computer research programs and other work. There have been scattered attempts to trace IT-induced shifts in the structure of research collaboration and conduct outside computer science and engineering, as well as some effort to consider research breakthroughs which might not have occurred without IT. To my knowledge, there has not yet been a comprehensive assessment of how the kinds of questions addressed and methods used may have shifted overall in response to IT.

Aggregated Impacts. For studies of aggregated impacts, analysts have tracked agglomerations of investments in IT and their possible relationship to national productivity growth, the level and composition of total employment, and the distribution of income among major labor force groups. Since estimates of aggregated impacts reflect an adding-up and netting-out of many non-homogenous applications and effects, they do not tell us much about the underlying processes which produced the aggregate picture or how the effects vary among actors and circumstances. Further, it is difficult to obtain all the data needed to estimate aggregated IT models because national statistical systems were developed prior to the IT revolution. Consequently, the findings of aggregated studies are sometimes inconclusive or inconsistent with the findings of more detailed work.

The Locus of Potential Impacts. Studies of where IT is used have produced information about the extent to which various technologies have penetrated

different organizational and population groups. Data about the locus of IT use in turn suggests the potential range and distribution of IT impacts. But identification and assessment of the impacts themselves requires more detailed study of IT in individual settings.

Economic Impacts in Business and Industry. Studies of IT applications in specific company and industry settings have searched for the most cost-effective methods for investment in IT, attempted to estimate their net cost-benefit ratios, examined their contributions to productivity growth, and considered how these vary depending on the company and industry circumstances. Insight has been gained from such studies, but work is underway to build more informative approaches. And new work is always needed as new technologies and new modes of application are developed.

Economic Impacts in Other Sectors. While researchers have been working to build more informative methods for assessment of economic impacts in business and industry, recent Federal legislation has mandated application of these methods to planning and assessment of IT investments in Federal agencies. Presumably, with work, these methods could be adapted to capture some of the IT impacts in other sectors, including the household, community, educational, and not-for-profit sectors (for example, by estimating IT-induced cost savings in the way individual household or organizational units accomplish particular tasks or purposes). Although economists have attempted to capture a larger range of effects than non-economists realize, there is no question that the full range of impacts spans a still-broader spectrum.

What Is the Potential Spectrum of Impacts? A priori, an impact would seem to be any change in how human beings conduct their affairs in order to meet their needs and aspirations. Any change that enhances human efforts to meet their needs and aspirations (for example, better information for farmers' use in expanding food production or households' use in improving food preparation--more healthful, tasty, or safe), would seem to have at least a potentially positive impact on quality of life. Any change that makes it harder to meet human needs and aspirations (for example, erosion of our natural resource base or increased social instability) would seem to have at least a potentially negative impact on quality of life.

How Can We Identify Impacts for Study? The question of whether a change can have an impact on quality of life and whether the impact would be positive or negative can be clear cut (e.g., reduces hunger) or a matter of opinion or circumstance (e.g., increases urban growth). As in other fields, criteria for determining the significance and positive or negative character of potential IT impacts derive from varied sources.

Agency Mission. For research conducted under a government research program, the mission of the agency can be used to derive criteria for identification of the significance and sign of impacts, for example, improved health, environmental quality, or national security. Of course, if the agency mission reflects unresolved conflict in the body politic, the criteria implicit in the agency mandate could be internally inconsistent and some sort of special analysis or netting-out algorithm would be needed. A special analysis or algorithm might also be needed to account for complementarities or conflicts with the mandated goals of other government agencies.

Shared Values. Shared values yield criteria for identification and assessment of impacts. For example, respect for privacy has prompted study of the extent to which IT allows optimal sharing of information while protecting individual privacy. Belief in social inclusiveness has spurred study of mechanisms that seem likely to produce access for all citizens to evolving IT systems. Commitment to democratic processes has elicited study of how the emerging information infrastructure influences citizens' relationships with their government.

Understanding of People and Institutions. The empirical understanding that social, behavioral, and economic scientists' and those in related fields have built about how people and organizations accomplish their ends also yields criteria for identification and assessment of IT impacts. For example, understanding the many functions served by the myriad interpersonal contacts of daily life has prompted study of how these have been altered by evolving IT applications. IT has greatly increased the kinds of contacts that individuals can have with organizations beyond (as well as within) their family and neighborhood. Social scientists are exploring the extent to which these new technologies might enable a richer set of contacts in all areas, or alternatively, enhance connections to the global community at the possible expense of ties to family and neighbors. Behavioral scientists ask whether links to the larger community (even at the expense of some contact with family or neighbors) might be more healthy for individual development and self expression.

Production and Satisfaction at Work. Since meeting human needs is generally considered to be the end purpose of work, labor economists and sociologists consider more than the production economies generated by IT in the workplace. They ask in what circumstances the application of IT yields a more satisfying environment for individual workers; and, in what circumstances, a less satisfying environment. They explore the feedback effect from worker satisfaction (or dissatisfaction) to the overall productivity of the organization.

Social and Institutional Parameters. An understanding of how social and institutional parameters are intertwined with the nature of human activities prompts researchers to explore IT-induced shifts in institutional structures. Investigators consider how the "boundaries" of organizations have changed; how

this has influenced the structure of production and other activities; how it has influenced the kinds of goods and services that are available; and who gains or loses from the shifts. In some instances, researchers examine whether the prerequisites for continued operation of the system are assured. For example, property rights are generally considered essential to the functioning of the market system. The IT revolution is requiring rethinking of modes for protection of rights in intellectual property.

IV. CONCLUDING COMMENT

A great deal of work has been undertaken to assess the applications and impacts of IT in our economy, society, and lives. A significant portion bears on quality of life. However, these studies are so extensive, scattered, and diverse that their results are not necessarily known or understood throughout the research community.

We do not yet have an integrated picture of the impacts of IT, their pattern in different settings, or their many interconnections to research in computer science and engineering.

Further work is needed. Next steps might include: development of a conceptual map that provides a comprehensive framework for capturing the full range of potential IT impacts, creation of an integrated information base for the many data sets and research studies now in existence, and initiation of further data collections and research efforts in order to fill gaps in knowledge.