

**PRODUCTIVITY AND THE ENACTMENT OF A MACRO CULTURE**

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## **Productivity and the Enactment of a Macro Culture**

This paper reports the puzzling results of a study which examined IT capital investment and productivity at three of the largest IT user sites in the U.S. for the period 1970-1990: Social Security Administration (SSA), Internal Revenue Service (IRS), and the Federal Bureau of Investigation (FBI). Based on detailed IT investment, employment, and output data over twenty years, we found that only one agency had achieved significant productivity benefits, a second agency had modest results, and a third agency achieved no results whatever. These results cannot be explained by traditional theories of productivity or how productivity is produced. We argue that IT-induced productivity results not simply from strategic choice, nor the operation of the invisible hand in the market place, nor simply from keen managers adjusting their organizations to an "objective" environment. Instead we propose instead a new theory in which productivity benefits derive from a larger macro-culture enacted by powerful institutions in an organizational field. We extend this analysis to the larger economy and examine how this new theory helps us understand recent claims that IT is finally having positive productivity benefits at the sector level, and also helps us understand how the current fascination with re-engineering and downsizing may be a self-fulfilling prophecy.

### **1. 0 Productivity: Concept and Measure**

There are several difficulties with the concept and measure of productivity. The first difficulty is understanding what productivity is and how it might be measured over interesting periods of time. The second difficulty is understanding how productivity is produced over interesting periods of time. These difficulties are largely independent--solving the former will not necessarily solve the latter.

The least controversial aspect of productivity research is its elementary definition as a measure of economic efficiency arrived at by dividing all outputs by all inputs (U.S. Department of Labor, 1988). Generally the focus is on units of output and input, and not prices, revenues or costs except where physical unit data is unavailable. Outputs are defined as economic goods and services, and inputs are defined as labor, capital, services, knowledge and energy. When

only price or revenue data is available, then deflators are used to adjust for inflation over specified time periods (usually no longer than a decade).

In many cases input data is not available and is too costly to collect because there are so many different inputs. The most widely used single factor productivity time series in the U.S. is output per hour which divides outputs by total labor hours of input to produce an output per hour measure. Other measures of productivity attempt to take into account the role of other inputs besides labor. Multifactor productivity measures like the capital-labor index and the KLEM (capital, labor, energy, materials and services) index are available for only the manufacturing sector (U.S. Department of Labor, 1988).

After these simple initial definitions and measurement techniques, controversy is rife. Some well known limitations of productivity research are:

(1) Natural units. Natural units of output may not be available. This forces researchers to base the value of outputs on the value of inputs, resulting in permanent zero productivity growth. Poor or no systematic productivity measures exist for sectors and industries like government agencies, non-profits, and educational institutions, along with the FIRE division (finance, insurance and real-estate), and services which account for more than 60% of the GDP (Gross Domestic Product) (Baily and Gordon, 1988). This means that for much of the "information economy", involving large occupational groups like managers, clerical workers, technical, professional and kindred workers (which do not correspond to the BLS industry divisions but which are of interest to scholars), have no natural outputs and have no economy-wide productivity measures. But, as we show below, for selected organizations it is possible to develop natural outputs and calculate productivity measures. Alternatively, researchers can change the output measure from physical units to a financial measure like gross revenues, and use a price deflator to account for inflation. This method does suffer from one critical fact: it fails to account for competition in markets which may reduce prices of outputs much more than inflation. Productivity may increase greatly in terms of output of units per hour, but the "worth" of this output in the marketplace may fall precipitously, and hence the value of the output per unit of labor input may decline. Physical productivity may rise while return on investment (ROI) declines.

(2) Substitution effects. Increasing output per hour of labor input can take place simply by substituting one factor of production for another and without change in intrinsic productivity for any specific input. For instance, by doubling the number of printers in an office, the output of clerical workers may rise not because of any intrinsic change in the productivity of clerical labor but simply because of the substitution of capital for labor. Likewise, better input materials (e.g. pre-printed forms) and more sophisticated external services (outsourcing of software development) also will enhance output per hour productivity measures. Panko and others have calculated that substitution of labor by capital, energy, materials, and outside services accounts for anywhere from 70 to 80% of productivity growth in the periods 1949-1983 (Panko, 1991; Nosworthy and Malmquist, 1985; Gullickson and Harper, 1987). This criticism is less convincing when focusing on the efficiency of the firm as a whole due to all causes rather than focusing on "output per labor input hour." When interest shifts to this broader productivity concern, the sources of productivity growth--whether by substitution or intrinsic change in productivity of a single factor like labor-- are of less interest.

A related puzzle involves substitution of occupational groups for one another and the interdependence of the manufacturing and service sectors. For instance, about 60% of the service sector output is purchased by the manufacturing sector, and about 40% of the manufacturing sector output is purchased by the service sector (Dornbush, et. al., 1988). Through capital investment, factories have experienced growing productivity resulting in fewer factory workers to produce the required output in the period 1960-1990. At the same time, sales, marketing, and financial employment has increased enormously. While factory workers declined from 25% to 18%, service sector employment expanded from 25% to 30% of the labor force (U.S. Census, 1991). This results in output per hour measures for factories increasing significantly, while office productivity stagnates, making measured office output per hour meaningless. Clearly a part of the productivity growth in factories is a result of supporting inputs from the service sector. A computer-based, micro-marketing sales force, for instance, can help a factory optimize its production schedule, reducing inputs of factory labor, making factory productivity soar.

(3) The quality of outputs. Even if outputs can be agreed upon, there is little or no accounting for changes in the quality of outputs. Measuring productivity over even moderate periods of time (greater than 3 years) runs into the difficulty that overtime product quality changes. Automobiles, computers, legal services, financial services, and health care services now have features and qualities which either did not exist in the past or which have greatly improved. A 1994 Power PC desktop computer of 100 MIPS power is just not the same as a 1984 PC AT of .5 MIPS even though both are counted as desktop PCs. Hence a unit of output is not constant over time even if it appears in our aggregate statistics as a constant unit.

(4) Problems of aggregation and levels of analysis. Findings on productivity can vary depending on the level of analysis adopted. For instance, while average productivity in a sector like the FIRE sector (financial services including finance, insurance and real-estate) may be quite low or even negative, specific industries and sub-industries like commercial banking or investment banking may show quite high productivity growth. While a sub-division like insurance may experience no productivity growth, some insurance firms may experience rapid productivity growth. Likewise within firms: the firm may show low productivity growth, but some divisions or profit centers may have excellent productivity growth. In general, aggregating to higher levels of analysis may disguise interesting productivity changes even as it illuminates overall trends in the economy. This problem becomes particularly intriguing when seeking to understand the impact of a single factor like information technology. Often, firms gather data on firm wide IT expenditures but they may not record information on divisional or profit center IT spending. This makes it difficult to assess the productivity impacts of IT. The positive impacts of IT spending in some profit centers may be overwhelmed by the poor performance of other profit centers in the firm.<sup>1</sup>

## 2.0 Productivity and Information Technology

Digital information technology--perhaps more than any other single technology in industrial history-- promised to have enormous impacts on economic efficiency and productivity because of its direct impact on an important factor of production, namely, information and knowledge. In advanced information economies, where information and knowledge workers



account for 60% of GDP ( Wolff and Baumol, 1987 ), it makes sense to believe that the vast improvements in computer hardware and software over the last 20 years, and the vast increases in IT investment both in factories and offices, would surely lead to widespread and powerful gains in productivity as a direct result of IT investments. But while U.S. spending on IT surged in the period 1970-1990, little formal evidence exists linking IT investment to productivity. There have been positive findings ( Osterman, 1986; Cron and Sobol, 1983; 1986; Harris and Katz, 1988; Bresnahan, 1986) , contradictory findings ( Attewell, 1991; Franke, 1987 ), outright negative findings ( Strassman, 1985; Berndt and Morrison, 1992; Loveman, 1988, 1991; Barua, Kriebel and Mukhopadhyay 1991; Roach, 1988), as well as qualified findings where productivity gains were found contingent on a number of environmental and management factors ( Weill, 1992; Franke, 1987; Bender 1986). In general, Attewell (1991: 10) concludes "Looking at these studies overall, what is impressive is the fact that despite very large investments in IT, productivity payoffs are elusive."

Several reasons have been adduced for the confused findings in the IT-productivity literature. Panko (1991) argues that the measures of productivity are too inexact (or non-existent) precisely in those sectors where IT investment has been largest (office work), and that assuming IT has a similar return on investment as other forms of capital (overall capital investment accounts for only about .6% of productivity growth per year), then the IT productivity impact would only be about .2% per year overall in the economy, and as large as .4% in office work. Panko concludes "Given the measurement and interpretation problems . . . it is doubtful that such small annual impacts could be separated from the "noise" in the analysis." (Panko 1991: 199). Criticism of government data sets generally conclude they have overstated increases in productivity, especially those due to information technology manufacture (Mishel 1988). Attewell (1991) essentially agrees with the negative findings, arguing that IT has caused a shift towards slower channels of communications (voice and face-to-face towards typed documents and e-mail), greater formalization of communication, a wasteful fixation with quality in documents based on the ease of using word processing packages, rapid change in software and resulting extended learning curves, an explosion in group generated paperwork not related to valuable outputs, and a burgeoning of middle management interested in using computers to extend their control and their own employment. Weill (1992) , in contrast, argues

that the efficiency impacts (return on investment) of IT depends on the types of applications built (transactional systems have large impacts on efficiency but not management information systems) and the political and social stability of the firm. More stable and consensual firms experience greater positive impacts. However this study was limited to only 33 firms in a single manufacturing industry (valves) which is very different from information and knowledge based firms and organizations which produce 60% of the GNP, and where, as Panko points out, most of the IT have investment and intensity occurs.

In perhaps the most comprehensive and representative sample of large industrial firms, Brynjolfsson and Hitt (1993) found striking evidence that the return on investment in IT was 68% in manufacturing and services, far greater than the return on other forms of capital (around 6%) , and that spending on IS labor was far more productive than non-IS labor. The study was based on data from 380 large, mostly manufacturing firms over the period 1987-1991. Brynjolfsson and Hitt attributed their highly positive findings to a much larger data set at the firm level than previous studies, and the currency of their data which they believe captured both the impacts of the huge growth in IT spending from 1985-1990, as well as the impacts of management learning how to use IT effectively.<sup>2</sup> They provide no evidence to support this speculation. They conclude that "Under this interpretation, our high estimates of computer ROI indicate that businesses are reaping the rewards from the experimentation and learning phase in the early 1980s." Over time they speculate that returns from IT investments should grow as firms and managers move up the learning curve, and as the investment in IT continues to swell. Unfortunately, recent work by the Economist Greenstein (1993) does not support the idea that productivity impacts of IT lag behind investments because of learning curve delays in implementing best practice.<sup>3</sup> Nevertheless, this is an important speculation for us because it suggests several organizational and historical mechanisms through which the productivity impacts of IT are produced, or, similarly, fail to appear.

### 3.0 Understanding the Origins of Productivity

Most investigations of IT-based productivity ignore the organizational processes which bring about productivity impacts (or the lack thereof). Yet the inescapable conclusion after reviewing the literature on IT and productivity is that the results in investment are variable, and



perhaps dependent on historical period (with earlier investments having lower returns, but also lower returns being associated with periods of high technological change and competence destroying change), management and staff learning, organizational stability, and organizational variables not yet identified. (Tushman, 1986).<sup>4</sup> The lack of theoretical sophistication in this area hampers our understanding of precisely how IT may or may not impact productivity. Using a classification schema developed by Astley and Van de Ven (1983), we can divide studies of productivity along two dimensions: voluntarism-determinism, and micro-macro (Figure 1)

**Figure 1**  
Theoretical Perspectives on Productivity

Macro (markets, populations)	Natural Selection  (3)	Collective Action  (4)
Micro (single firm)	System Structural  (2)	Strategic Choice  (1)
	Deterministic ----- Voluntaristic	

Most studies of productivity in the business literature are studies of a single firm with a proactive management that implements a "strategic" system that has powerful, positive impacts on productivity (Applegate, Cash, and Mills, 1988; Frito-Lay, 1993; Baxter-AHSP, 1991) [Strategic Choice Model 1]. Almost all of the so-called re-engineering literature falls into this category (Hammer and Champy, 1993). In these studies managers scan their environments, watching competing firms, technologies, business metaphors and markets; based on these assessments, managers enact both environments and organizational structures, enfusing both with their meanings, ideologies, visions, and understandings of how to conduct business (Weick, 1979; 1993). Managers choose which environmental niches to enter and exit, which products to

manufacture and how. Over time managers "experiment" by creating new programs and routines (Starbuck, 1983) and they "learn" (Porter, 1985 ; Attewell, 1992; Kling and Iacono, 1984; Huber, 1990). IT has a positive impact on firm productivity because managers correctly enact their firm's environment, and structure, and they creatively develop a set of firm-level action programs and routines which result in raising productivity.

A growing number of IT-productivity researchers employ a system-structural and contingency view [System Structural Model 2] in which organizations must learn to adapt to their changing environments, changing technology, and resources (Weill, 1992; Brynjolfsson and Hitt ,1993; Sproull and Kiesler, 1991; 1992 ). The focus is on individual firms. In this view environments are given, "objective," and managers reactively must adjust their firms structure, culture, size, and use of IT to these environments. Such adjustments in the organizations structure are either "functional" or not depending on their impact on the ultimate goal of the firm which is survival at least, efficiency at best (Lawrence and Lorsch, 1967; Galbraith, 1979; 1983). IT-enduced productivity gains result when managers correctly perceive environmental changes (determined by exogenous forces), when they structure roles and hierarchies to "fit" this environment, and when they "learn" how to use IT effectively. For Brynjolfsson and Hitt (1993), as an example, productivity from IT comes after managers go through an extended learning process, and after they correctly perceive the enormous ROI available from IT.

The disciplines traditionally concerned with productivity --industrial economics, economic history, micro-economics, and population ecologists in sociology-- form a third view of productivity [model 3 above]( Chandler, 1962). These researchers shift the focus from the firm to markets and market niches (or environments with limited resources), to populations and communities of organizations (Hirsch, 1975; DiMaggio and Powell, 1983; Hannan and Freeman, 1977). Organizational structure and management actions are largely determined by economic markets and available technologies. The key concepts are variation, selection, and retention, along with birth rates of new firms and death rates of old firms. As environments change, new firms are continually being formed in essentially random patterns; when their behavior finds external resources in a market niche, the firms thrive and multiply. Eventually, as environments change, these firms lose resources and die out. Environmental selection is the key actor--not managers. Organizations are brittle, and faced with "frame breaking changes" in technology and

environments, they tend to die (Tushman and Anderson, 1986; Starbuck, 1989). Researchers in this perspective generally use long term (20-50 year) industry or sector data to study patterns of organizational birth and death (McKelvey and Aldrich, 1983). A related but different perspective focuses on institutional isomorphism (the fact that organizations in the same organizational field over time come to look and act alike) (DiMaggio and Powell, 1983). Rather than attribute the similarities among organizations in the same population niche to environmental selection, DiMaggio and Powell (1983) attribute organizational isomorphism to coercive, mimetic, and normative pressures on organizations to adopt the "correct" processes and structures. For instance, firms respond to coercive State pressures to adopt standard operating procedures, they "model" themselves on successful organizations (and share personnel and consultants with one another), and they willingly adopt professional norms of structure and conduct.

As far as we know there are no empirical studies employing a natural selection theory in IT-related productivity research although several theoretical tracts come close to this position at times. All IS literature that has an aura of inevitability in which managers must change their organizations (reduce hierarchy, lower the decision making locus, empower workers, etc.) because of a technologically or socially determined environment or face extinction fall into this type of reasoning. Malone, Yates, and Benjamin (1987) argue, for instance, that over time firms must inevitably move towards a greater reliance on markets rather than hierarchies to conduct business because firms who do this will be more efficient. Sproul and Kiesler (1991) argue that the new telecommunications technology will shape the form of new successful organizations in the future. The new technology will create new kinds of firms where jobs are widely physically distributed, authority is decentralized, and information is widely shared. Drucker (1988) argues that firms must reduce organizational levels by using new information technology or face extinction.

Throughout most of these theoretical tracts is the clear implication that firms which fail to adapt to the new IT-determined environment in the proscribed manner will be extinct, driven from the market by svelte new firms employing the latest "best practice" in tech-organization design. There is precious little data to support any of these claims and given the newness of information technology, and its rapid rate of change, there simply are no long term data sets yet

to confirm or deny these propositions . The more general literature on technological change ( Sahal, 1981; Tushman and Anderson, 1986) focuses on the extinction of firms caused by disappearing market niches brought about by technology change per se and offers little hope that adopting the "right" organizational firm could have saved any of the now extinct firms. Could organizational change have saved the Lehigh Coal Company, once one of the largest 25 corporations in America in 1919? History suggests the answer is no, and that very few organizations survive more than 50 years (Starbuck, 1989).

A fourth category of theory which can help explain productivity changes caused by IT is the collective action view (Pfeffer and Salancik, 1978; DiMaggio, 1989; Abolaffia and Kilduff, 1988; Fombrun and Abrahamson, 1992). In this view organizations form networks of interaction along lines of competition, alliances, and resource dependencies. These networks define organizational fields (sets of interdependent organizations fulfilling particular social functions (Fombrun, 1986)), organizational and industry boundaries (Porac and Thomas, 1990), and macro cultures (Sproull, 1981). Macro cultures are the bedrock shared understandings and expectations which arise from organizational fields and which define acceptable behavior, which rank organizations in the field (Fombrun and Shanley, 1990), define acceptable "recipes" (Grinyer and Spender, 1979), standard procedures, routines, and strategies to be used, and acceptable structures to employ (Meyer and Rowan, 1977). Macro cultures differ from firm level micro cultures because they originate outside the firm from the organizational field, generally have multiple participants, and reflect the collective enactment of shared beliefs about the environment. Change takes place through bargaining, conflict, negotiation with significant others in the organizational field, and through changes in the macro culture. The concept of a macro culture is a cognitive concept based on the observation that organizations acting in concert with others can in fact change and enact their environments through trade associations, lobbying of governments, professional societies, competitive alliances with firms up and down the value chains, and through competition with others in their organizational fields. The role of managers here is to interact with other organizations, and to participate in the larger macro culture of which their firm is a part.

There is a considerable empirical literature in IS that uses a collective action perspective although it has received less attention from popular media than it should have. Virtually all the

literature on public sector uses of IS takes the view that adoption of IT in American government was heavily influenced by macro level political, social, and cultural factors (Laudon, 1974; Kling, 1974; King and Kraemer, 1986; Laudon, 1986). Detailed analyses of specific private sector IT implementations (Markus, 1983; ) and general analyses of the social construction of IT systems (Keen 1981; Kling and Iacono, 1988) describe the role of micro political factors and point to larger macro cultural factors in the propagation of computing, computing styles and applications. This literature argues that IT implementations are negotiated and enacted orders reflecting the strength, interests, and values of participants in the development process.

Collective action theory has not been applied before to understanding productivity changes resulting from IT. Below we present data on the productivity impacts of IT at three different agencies of the Federal government over the period 1970-1990. We demonstrate that a collective action perspective provides valuable insights into the IT productivity relationship.

#### **4.0 Information Technology at SSA, IRS, and the FBI, 1970-1990**

The Social Security Administration (SSA), the Internal Revenue Service (IRS), and the Federal Bureau of Investigation (FBI) are among the largest and in some areas the most sophisticated users of information technology in the civilian economy of the U.S. SSA began developing automated large file handling techniques with IBM as early as 1940; the FBI began using digital computers in the mid 1950s. The IRS began using digital computers much later, in the early 1960s.

SSA employs 65,000 workers to maintain earnings data on over 200 million American citizens who are current or former labor force participants, distributes 40 million checks each month, and administers a number of complex, earnings based social welfare programs the largest of which is the Old Age and Survivors Insurance program. SSA maintains a centralized organizational structure established in 1936, including a large centralized mainframe-based data center in Baltimore, Maryland, connected via satellite to 10 regional centers and 1300 local SSA offices throughout the country. Following the near collapse of its data processing systems in the late 1970s, SSA began a \$2 billion program to rebuild its systems and re-design its organizational and work processes (SSA, 1993).



IRS employs 120,000 workers to maintain earnings data on 200 million working Americans and 4.4 million other reporting entities, and to administer the tax laws of the United States. IRS maintains a centralized organizational structure originally established in the 1920s including a large centralized mainframe data center in Martinsburg, Virginia, connected via a variety of telecommunications links to 10 regional service centers where paper tax returns are initially processed into computer tapes which are then transported physically to Martinsburg. Despite massive increases in computer processing power, by most accounts the IRS administrative systems neared collapse in the late 1980s. IRS systems have changed little since the early 1960s except for hardware upgrades, and the system is at the limits of its performance capability. The IRS is currently engaged in a \$6-8 billion modernization program. (National Research Council 1992; GAO 1990).

The FBI employs 24,000 workers to investigate violations of federal statutes and provide criminal investigation and criminal history records to 58 local FBI offices and more than 64,000 state and local police agencies in the US. The FBI maintains a centralized organizational structure established in 1934, including a large centralized mainframe based data center in Washington D.C. (supported by three regional processing centers). The FBI maintains a database of over 200 million fingerprint records on civilians, and armed forces personnel, 86 million of which are criminal histories. 10 million of the criminal history records are fully computerized at the National Crime Information Center along with a variety of stolen property and warrant files. About 500,000 transactions per day are processed at NCIC. The FBI is currently engaged in a \$100 million upgrade (NCIC 2000) involving significant enhancements to the central database and installation of 64,000 terminals around the country (U.S. Department of Justice, 1993).

### *Data*

The findings reported here are based upon a larger study of long term historical trends in information processing at the three agencies in the period 1940-1994. The study is based on 155 interviews with agency management, users, and vendors at federal, state and local levels in the period, General Accounting Office investigators, members of Congress, Congressional staff, 1985-1994. In addition we gathered detailed quantitative data from a



variety of private, federal agency, federal budget, and Congressional documents on the following variables:

*Employment:* Detailed occupational data on each agency, 1940-1990.

*Workload:* Detailed data on the number of forms processed (SSA and IRS), clients, services provided to clients, and (FBI) fingerprints stored and record requests processed, 1940-1990. Other related work load data not reported here was also collected.

*Installed base:* Detailed data on specific installed mainframe and mini computer machines, capacities (MIPS), and manufacturer. This data was gathered from GSA (General Services Administration Annual surveys, interviews, and agency reports).

*Budgets:* Detailed budgetary data on investment in information technology capital (communications, data processing, and office equipment expenditures, 1940-1990), non-information technology capital, labor, services, and real-estate.

*Wages:* Detailed wage data on employees, 1940-1990.

Only the analyses concerning IT impacts on productivity are reported here. The analysis is limited to the period 1970-1990 because this period contains the most precise data, and it is the period of intensive investment in IT. Forthcoming papers describe occupational and employment impacts, patterns of budgetary growth, and patterns of technological advancement and diffusion.

## Measures

Our interest in this paper is in identifying and understanding the relationship between productivity and the installed base of computing power over a twenty year period. There is little doubt that we have reasonably precise measures of IT capital installed (both monetary values and physical (MIPS) and the size of the labor force. Measuring the dependent variable, productivity, is less precise in this data. The dependent variable varies by agency but focuses in all cases on the labor productivity with respect to the primary work loads of the agencies. In the case of SSA, the dependent variable is the total number of clients served by the agency in each year divided by the total number of employees at SSA. At the IRS the dependent variable, productivity, is measured by the number of tax forms processed per employee. In the case of the FBI, productivity is measured by the number of fingerprints of all kinds (computerized and non-computerized) stored by the FBI per employee.

As with all productivity measures, ours suffer a variety of problems. Not all the work at any of these agencies is entirely captured by these measures. Clearly a core mission of the FBI since the 1930s has been the creation, maintenance, and growth of its criminal history files and civilian fingerprint based identification systems (Laudon, 1986). Yet one third of the FBI labor force are investigators who, while they contribute to and draw from the fingerprint files, are not themselves actively engaged in fingerprint and record processing. Better measures for FBI output were sought, but the agency was uncooperative at every turn. (5)

IRS also has a large number of people devoted exclusively to processing tax forms and also a significant number of employees devoted to tax compliance and enforcement. At SSA there are actually only a few employees devoted to maintaining the records while most employees are devoted to providing service to SSA clients.

For the IRS and SSA, the nature and quality of the work that is being performed also changed over time. This is a problem that occurs for measuring productivity changes for any service based organization. We know of no data source that measures changes in the output quality of any of these three agencies. One source of quality changes is the changing complexity of the work load. Although we developed several measures of complexity of work for this time

period, none contributed useful information to the problem of productivity at these agencies or altered the results reported here.<sup>5</sup>

The best measure we have of productivity changes is thus the simple one of the measure of total output divided by total labor, which is the measure used by the Bureau of Labor Statistics in estimating changes in government productivity [U.S. Dept. of Labor, BLS 1988]. While our measures of productivity are admittedly gross, we feel they roughly shadow real changes in productivity at these agencies no matter how that is measured. Our data extend over a twenty year time frame and they roughly track the changes in productivity experienced in non-governmental information work sectors like FIRE (Finance, Insurance, Real-estate). For these reasons we believe our measures reflect real changes in productivity at these agencies.

## **Findings**

The null hypothesis we are testing is (1) there is no relationship between installed IT capital and productivity. Figure 2 presents a graphical display of the data for the three agencies.

**Figure 2**  
**Productivity, MIPS, Employment, and Workload by Agency**

Clearly, there are significant differences in the changes in productivity among the three agencies. At the FBI, productivity has remained fairly constant while computing power has increased. FBI workload and the size of the labor force have both varied. At IRS, productivity has declined since 1982 while workload, labor force, and installed computer capacity have steadily increased for the entire two decades. At SSA, productivity has increased since 1982, while workload and installed computer capacity has increased during the entire time. The size of the SSA's labor force though has varied, increasing and then, since 1983, decreasing steadily.

Table 1 presents summary statistics for these various measures and includes the simple correlation matrix among the variables, again, by agency.

Figure 2 a FBI

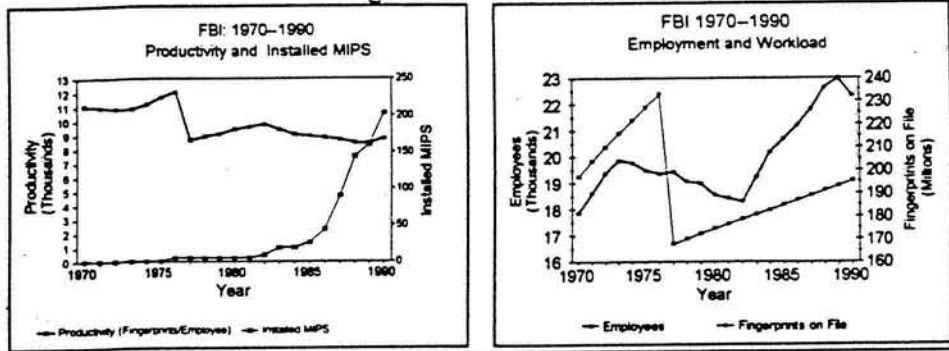


Figure 2 b IRS

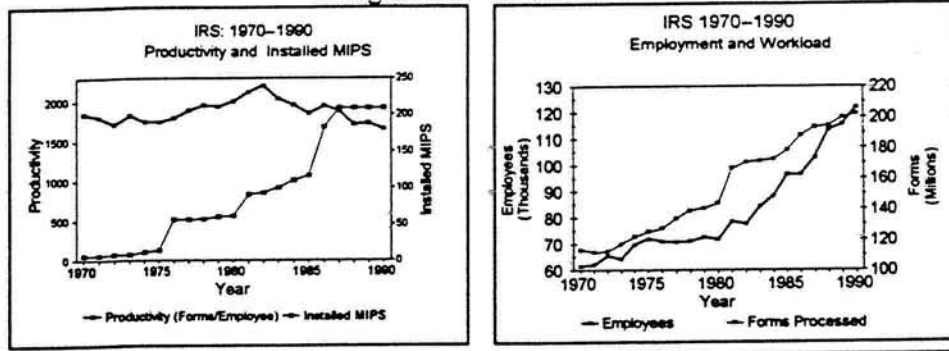


Figure 2 c SSA

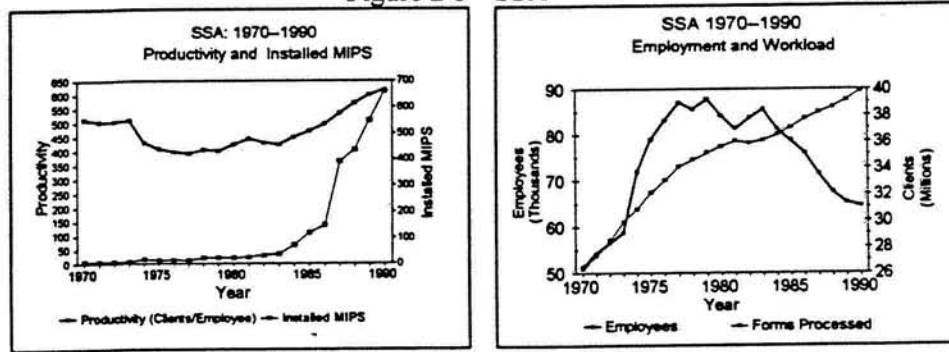






Table 1: Summary Statistics by Agency, 1970--1990  
Correlations and Descriptive Statistics

Table 1a Federal Bureau of Investigation

	Fngr/Emp	FINGERPR	EMPLOYEE	MIPS
Fingerprints per Employee	1.0	0.80818	-0.53653	-0.55480
Fingerprints on File	0.80818	1.0	0.06163	-0.06042
Number of Employees	-0.53653	0.06163	1.0	0.87527
MIPS	-0.55480	-0.06042	0.87527	1.0
Mean	9738.94	192926961	19901	35.86
std.	1162.74	19175603	1490.27	60.21
Minimum	8411.22	167700416	17847	0.50
Maximum	12043.	232933762	22968	203.00

Table 1b Internal Revenue Service

	Form/Emp	FORMS	EMPLOYEE	MIPS
Forms per Employee	1.0	0.11555	-0.24444	-0.05603
IRS: Tax Forms	0.11555	1.0	0.93355	0.96367
Number of Employees	-0.24444	0.93355	1.0	0.95914
MIPS	-0.05603	0.96367	0.95914	1.0
Mean	1874.24	153280459	82110	89.50
St. Dev.	142.10	32003645	18536	74.41
Minimum	1656.03	111447000	61290	209.28
Maximum	2201.80	201714638	121806	6.68

Table 1c Social Security Administration

	Clients/Emp	CLIENTS	EMPLOYEE	MIPS
Clients per Employee	1.0	0.24101	-0.72326	0.82464
SSA Beneficiaries	0.24101	1.0	0.49247	0.66059
Number of Employees	-0.72326	0.49247	1.0	-0.25838
MIPS	0.82464	0.66059	-0.25838	1.0
Mean	472.21	34388908	73990	125.66
Std. Dev.	68.27	3930274	11688	199.54
Minimum	391.46	26228629	51202	8.41
Maximum	617.69	39832125	87754	660.77

The model that we will use to analyze the data is deliberately simplistic: productivity is treated as a linear function of the total number of employees, total measured workload, and installed computer capacity (mainframes and mini computers) measured in MIPS. The advantage of this model is that it is easily understood: *ceteris paribus*, as workload increases, productivity increases; as employees increase, productivity decreases. The variable of interest is MIPS and the question we are trying to explore is whether or not productivity increases as the installed base of computing power increases. The disadvantage is that the model is not likely to be useful outside the range of the data. Also, our model is not a production model and does not provide insight into elasticities, substitutions of labor for capital and scale effects nor was it intended for those purposes.

Table 3 presents the results of a regression analysis of the equation:

$$\text{Productivity} = B_1 * \text{MIPS} + B_2 * \text{Employee} + B_3 * \text{Workload},$$

where the variables are as previously described. PRODUCTIVITY is the measure of output per employee; MIPS is the installed base of computer capacity; EMPLOYEE is the size of the labor force for each year; WORKLOAD is the agency output measure.<sup>6</sup>

Clearly the coefficients for both the labor force and the agency workload have the correct signs in all three equations. The important question of course is the impact that computer capacity (MIPS) has on productivity.

Table 3: Regression Analysis, by Agency

Table 3a Federal Bureau of Investigation:

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob >  T	Standardized Estimate
INTERCEPT	1	9600.409141	258.57128513	37.129	0.0001	0.000000
FINGERPR	1	0.000051563	0.00000052	99.552	0.0001	0.850369
EMPLOYEE	1	-0.494712	0.01375513	-35.966	0.0001	-0.634067
MIPS	1	0.995669	0.34040479	2.925	0.0094	0.051564

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	3	27007776.403	9002592.1344	4852.872	0.0001
Error	17	31536.80478	1855.10616		
C Total	20	27039313.208			

Root MSE	43.07094	R-square	0.9988	Durbin-Watson D	0.883
Dep Mean	9738.94284	Adj R-sq	0.9986	1st Order Autocorrelation	0.270
C.V.	0.44225			(N=21)	

Table 3b Internal Revenue Service

Variable	DF	Parameter Estimate	Standard Error	T for Ho: Parameter=0	Prob >  T	Standardized Estimate
INTERCEPT	1	1732.942098	83.10285796	20.853	0.0001	0.0000000
FORMS	1	0.000012106	0.00000058	20.934	0.0001	2.7263927
EMPLOYEE	1	-0.020677	0.00094250	-21.939	0.0001	-2.6972159
MIPS	1	-0.184058	0.31511874	-0.584	0.5668	-0.0963742

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	3	395683.68382	131894.56127	273.987	0.0001
Error	17	8183.62186	481.38952		
C Total	20	403867.30568			

Root MSE	21.94059	R-square	0.9797	Durbin-Watson D	0.841
Dep Mean	1874.24013	Adj R-sq	0.9762	1st Order Autocorrelation	0.481
C.V.	1.17064			N=21	

Table 3c Social Security Administration

Variable	DF	Parameter Estimate	Standard Error	T for H0 Parameter=0	Prob >  T	Standardized Estimate
INTERCEPT	1	517.494138	14.00047198	36.963	0.0001	0.000000
CLIENTS	1	0.000011054	0.00000084	13.215	0.0001	0.63632
EMPLOYEE	1	-0.005835	0.00021859	-26.692	0.0001	-0.99884
MIPS	1	0.050030	0.01484321	3.371	0.0036	0.14622

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	3	92887.23821	30962.41274	1550.215	0.0001
Error	17	339.54073	19.97298		
C Total	20	93226.77894			

Root MSE	4.46911	R-square	0.9964	Durbin-Watson D	1.319
Dep Mean	153.22521	Adj R-sq	0.9957	1st Order Autocorrelation	0.212
C.V.	0.02912			(N=21)	

For the FBI, the coefficient on MIPS is positive and significant (1.00, P-value=.0094). For the IRS, MIPS is negative and not significant (-0.18, P-value=.567). For Social Security, MIPS is positive and significant (.05, P-value=.0036). The implications of these findings are discussed below.

The results of the analysis are puzzling but not untypical of the previous research: in some cases productivity rises with investments in IT, and in other cases productivity is not effected. The graphs in Figure 1 show that, for SSA, investment in IT capital rapidly expanded (increasing IT by a factor of 73 and IT capital/employee by a factor of 58 in the period 1970-1990) and that productivity closely followed these massive "Big Iron" investments. For the IRS, a very different pattern emerges: a 30 fold increase in IT capital and a 19 fold increase in IT capital/employee occurred in the period but productivity declined. At the FBI, a 200 fold increase in IT and a 350 fold increase in IT capital/employee resulted in essentially no change in productivity.

The results of the regression analysis are also interesting. As expected at SSA, the coefficient for MIPS/employee is positive and strong ( $p < .003$ ). At SSA, a 1% increase in productivity occurs for each 100 MIPS/employee increase. At IRS, the coefficient for MIPS/employee is weak and insignificant, that for LABOR is strong and very negative. Adding MIPS at IRS, *ceterus paribus*, did nothing while adding employees brought large declines in productivity. Every 1,000 employees added by IRS in this period of rapid employment growth reduced productivity by 1%. The picture at the FBI is more sanguine. The MIPS/employee coefficient at the FBI is positive and significant (.05,  $p < .009$ ) but only about one-third the strength of the SSA coefficient (.14). At the FBI, a little over 200 MIPS/employee increase is needed to raise productivity 1%. However, while IT capital has modest positive effects at the FBI, it is insufficient to overcome the effects of hiring additional workers (which suppresses productivity). Overall then the FBI productivity drifts lower despite a 200 fold increase in IT capital even though the measure of productivity we use should be greatly impacted by IT spending.

## Discussion

One reviewer raised questions about the technical adequacy of our model which we answer in the end notes.<sup>7</sup> We prefer here to focus on the substantive issues concerning the social construction of productivity. Obviously, each of the agencies made very different uses of IT capital in this time frame. The MIPS/employee coefficients are measures of how efficient management was in converting IT capital into bottom line productivity (Weill, 1992). But the question is, why did these differences appear? We have three agencies each in the same administrative-political culture (the federal government), each with very information intense services and production functions, each heavily dependent on information technology, and each with long histories in developing information technology systems. There are of course technical differences evident in these data. For instance, SSA increased its IT capital endowment/employee by 58 fold, the FBI by 350 fold, and the IRS “only” by 19 fold. Is the answer that truly massive investments in IT are needed to bring about productivity benefits? We think not. Instead a careful analysis of the macro cultures in which these agencies participated goes a long way in explaining how the productivity numbers above were socially constructed by the participants.

### *Comparative Macro Cultures*

A brief review of the political administrative environment of the three agencies in this period sheds a good deal of light on how they used information technology differently and obtained different results. SSA entered the 1970s as an exemplar of leading edge mainframe technology use in the Federal government. But during the 1970s several new programs were added to their agenda (Supplemental Security Income, Black Lung, Medicaid) which brought millions of new clients and thousands of pages of new regulations to learn and implement for SSA employees. At the same time, SSA failed to upgrade their systems as the number of clients rapidly increased with an aging population. Several efforts at system modernization failed in the mid and late 1970s, and by 1980 systems nearly failed on several occasions to issue checks on time. Employment had ballooned by 30% in the 70s to cope with rising demands and failing systems. Senior executive turnover began to accelerate in the late 1970s, and internal conflicts with a unionized labor force expanded. Both Executive agencies (OMB, Office of the

President, DHEW) and Congressional Committees became severely critical of SSA ( OTA, 1986)

As the leading accomplishment of the New Deal, SSA was an unpopular agency in the Reagan administration. The President appointed several temporary Commissioners to head the agency, who in turn developed a plan to modernize the agency's systems in the 1980s. This billion dollar Systems Modernization Plan was accepted by the White House on one condition: SSA would have to terminate 25,000 employees as evidence that the systems modernization would in fact lead to higher levels of productivity. This deal was ultimately agreed to by key Congressional Committees who oversaw SSAs budget. SSAs senior management agreed in principle, but had a difficult time implementing the cutbacks. After firing one acting Commissioner, a new permanent Commissioner was appointed in 1986 (the first permanent Commissioner in the Reagan era) who agreed to implement the cutbacks. Several internal senior management shifts also occurred in 1986, including the creation of a new office of Deputy Commissioner of Systems--a CIO like position. (OTA, 1986). From a peak employment of 87,000 in 1979, SSA has shrunk its labor force by 23,000 positions.

In the end, SSA had little choice but to greatly reduce its labor force, develop new business procedures, new supporting software in order to survive the 1980s, and demonstrate that it could become more productive. After the expenditure of nearly \$2 billion in the largest civilian system re-build to date, SSA enacted a new macro cultural environment which had many participants (the President, OMB, and Congress). These external actors in SSA's organizational field, acting in concert with SSA senior management, created a powerful set of cultural expectations, backed up by the power of the budget.

Very different conditions obtained at the IRS. As a money gathering agency in a period of stagflation (the 1970s) , and later in the 1980s high budget deficits, the IRS was a very popular agency in the Executive Branch and in Congress. There is nothing more important to the White House and the Congress (or to any government) than the collection of taxes. As a result, historically there has been little in-depth, critical oversight of the agency (Burnham, 1989). Through much of the 1970s the IRS experienced a relatively stable legal-regulatory tax environment, and its systems developed in the 1960s were sufficient. The Carter administration turned down a major effort to re-build IRS systems ( OTA, 1977). However, changes in tax law



in 1984, 1986 and 1987 began to wreak havoc on existing systems and personnel, and made for great confusion in the agency. By the mid-1980s IRS systems fell far behind in issuing tax refunds. The IRS lobbied Congress for more people and more computing hardware using misleading data, alleging ever increasing non-compliance (even though later analyses found these reports ignored simple adjustments, see Long and Burnham, 1990). Several efforts to patch its systems in the 1980s failed, and in one instance led to a significant loss of tax receipts. Despite this chaos, there was little senior management turnover in the agency and neither the White House or Congress demanded that senior managers be held accountable. Instead, both the President and Congress accepted IRS' claims that it simply needed more employees and more computers to solve its problems. There never were any demands for IRS to "modernize" its systems to the point where people would be fired. Quite the opposite. The President and Congress approved in this twenty year period a doubling of IRS employment, from 61,000 in 1970 to 121,000 in 1990. Currently, IRS is involved in its third attempt at modernization: a \$6-8 billion Tax System Modernization program (GAO, 1990).

The FBI shared a similar friendly political administrative macro environment. With a few exceptions in the 1960s and early 1970s, the Office of the President and key Congressional Committees have treated the FBI with great deference (Laudon, 1986). Even after the death in 1974 of its powerful leader and protector, J. Edgar Hoover, the FBI remained a cornerstone of both the Carter and Reagan administration's anti-crime policy. Although few new programmatic responsibilities came its way, throughout the 1980s the FBI steadily enhanced its existing fingerprint record technology, mainframe installed base, and developed many new applications in expert systems, telecommunications, neural networks, and database search techniques. Employment at the agency grew a modest 22% from 18,000 in 1970 to 22,000 in 1990. In the FBI's macro culture composed of key executive, legislative, and regulatory actors, there never were any calls for the FBI to "become more productive." There were indeed questions about the effectiveness of the FBI in general, and concern about the FBI's growing surveillance capabilities, but never any call for more productivity despite a 15 fold increase in its installed IT capital.

Yet despite a non-demanding macro cultural environment, the FBI nevertheless did achieve a modest amount of productivity impact from its systems investments (not enough to

overcome the effects of hiring additional workers in this period, but a positive impact nevertheless). Why? Here we would point to internal organizational factors: long term senior management commitment to systems development, a history of steady improvement--if not innovation-- in basic mainframe record systems, long term senior management stability in the systems area, a comparatively simple task--gathering, storing, disseminating fingerprint and other records which have changed little in twenty years, and tasks directly amenable to productivity enhancement through IT investments (Weill, 1992). These micro level structural and cultural factors were sufficient to produce modest productivity impacts from IT capital spending.

## Conclusion

We have argued that an important factor in understanding how IT induced productivity is in fact produced is to look carefully at the macro culture in which an organization participates. When this macro culture demands productivity returns after or in anticipation of investments in IT, either the organization responds appropriately or it loses rank, influence, power and potentially its existence insofar as it is dependent on external organizations for resources and legitimacy. Typically the organization participates in the creation of these macro cultures, and they are collectively enacted. IT may make enable an appropriate response, and it may be a necessary condition for achieving higher levels of productivity in response to macro culture demands. But alone IT capital is not a sufficient condition for achieving higher levels of productivity as ours and other data show.

This argument may well apply to the so-called turnaround in productivity numbers observed by Roach. To the embarrassment of many in the IS community, Roach reported in 1987 that there was little evidence at the sector level of IT investments leading to higher productivity. But by January 1992 Roach was reporting that IT investments were indeed having a positive impact on productivity: service sector managers were aggressively "right-sizing" their back office operations that for years were ridden with overcapacity and inefficiency: "Restructuring appears to be the only answer [to achieve productivity]. And, in our view, corporate restructuring strategies will be increasingly focused on "technology deliverance"-- redirecting the tools of information technology toward measurable productivity paybacks

(Roach, 1992: 1). This turnaround in productivity statistics is not the result of management learning how to use IT but instead a result of --we argue--of business macro culture participants like pension funds, large institutional investors, popular business journals, commentators like Roach, and others demanding much better returns on corporate investments as evidenced by productivity results and ultimate stock price performance. This same macro culture now extols the virtues of re-engineering, re-designing business processes, and capturing the "business value" of information systems. These slogans have become expectations of approved behavior, and they have come to dominate the public announcements of corporate CEOs, business school Deans, and major consulting firms. The strength of these macro cultural expectations is enormous and more than sufficient to cause organizations to ensure that productivity will indeed follow IT investments.

An illustration of the power of this contemporary business macro culture was given in an interview of CIO of a large Mid Western insurance firm that had just undergone a \$28 million, five-year re-engineering project which resulted in laying off 1,000 middle managers (about 20% of the labor force). In response to the question "What is re-engineering as you have come to practice it in your company?" he responded:

"The first thing we did on this project was to fire half of the middle managers who worked here. Even though we were the best in the industry in terms of timely and quality service, we knew we could be better, we should be better. The second thing we did was to put together a committee of some remaining middle managers and a few senior managers and send them around the company to figure out what the fired managers used to do. No body really knew. As it turns out, they didn't do much anyway! The third thing is we told this committee to come up with ways to get the same amount of work higher quality and less people. Well soon we had a proposal on our desk and together we worked out the plan for new business procedures and new systems to support those procedures."

Our point is that productivity is in part a socially enacted macro-level affair measured by well known artifacts. Productivity does not simply result from strategic choice--as if those choices occur in a vacuum. Neither does productivity result automatically from appropriate behaviors randomly induced and selected out for survival by an invisible hand marketplace, or a competitive environment with limited resources. And neither does productivity simply result

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er productivity reflects at least in part the enactment of a macro  
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### Data Sources Notes

**General:** Several federal sources were used in parts of the study to fill in gaps in data, and fill-in background knowledge on budgetary expenditures. See the following:

Executive Office of the President. "Budget of the United States Government". United States Government Printing Office, (various years).

"Annual Report Commissioner and Chief Counsel Internal Revenue Service" (various years)

U.S. Department of Commerce, Bureau of the Census. *Statistical Abstract of the United States*. (various years)

Social Security Administration. *Social Security Bulletin: Annual Statistical Supplement, 1991*. Superintendent of Documents, U.S. Gov. Printing Office.

### Employees:

There are several sources of total employment and none of the sources agree with each other. The annual Executive Budgets of the U. S. Government provide the best source since it has contained employment data since the 1940, is subject to more reviews than most other sources and it is widely available to the public. In addition, we would like to thank TRAC at Syracuse University, and Sue Long, for providing us with detailed employee head count data for the years 1970-1990.

### Workload measures

**Social Security Administration** publishes annual statistics on the number of SSA clients. The Table 5.A4 (pl63) of the 1991 Statistical Supplement of the SSA Bulletin contains number of

OASDI (Old-Age, Survivors, and Disability Insurance) beneficiaries and is the Workload data used for SSA.

Internal Revenue Service publishes an "Annual Report: Commissioner and Chief Counsel: Internal Revenue Service", which contains tax return data. A summary of this data is found in "Statistical Abstract of the United States". These sources agree and both were used.

Federal Bureau of Investigation publishes an annual report that contained the fingerprint data (total number of prints in the FBI's files) but discontinued this in the 1980s. From 1980 on we relied on agency annual reports and interviews with FBI officials. In addition, we relied on annual reports of the Department of Justice, of which the FBI is a Bureau.

### Computer Capacity (MIPS)

MIPS capacity data is derived from GSA annual reports of computer inventory in the federal government. (See also Eindor, 1985]. We would like to thank the Babbage Institute at the University of Minnesota for supplying us with the detailed GSA annual surveys of computer inventory in the federal government, 1970-1990.

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<sup>1</sup> This has probably occurred in FIRE industries. While significant investments were made in IT to support operations, leading to important productivity advances in certain profit centers, poor loan practices in the 1980s greatly reduced insurance and bank earnings overall. Hence, while IT investment soared, overall FIRE productivity defined as revenues produced (output) per employee (inputs) stagnated during the 1980s.

<sup>2</sup> While IS professionals inside and outside of academia will no doubt rejoice at these optimistic findings of Brynjolfsson and Hitt, the authors themselves have pointed out in discussions at ICIS where the paper was given that there is no explanation in economics for why the return on IT capital is so much larger than non IT capital. Capitalists should invest in factors of production to the point where the marginal returns on investment across all factors are roughly equal. With returns on IT capital being 10 times the returns of non-IT capital, managers have apparently been acting irrationally and have severely under invested in IT.

<sup>3</sup> Greenstein (1993) found that for the period 1968-1983 best hardware mainframe practice lagged "mean" mainframe practice by only 6-7 years, roughly half the lag of other non-IT technologies. This does not totally vitiate the claims of Brynjolfsson and Hitt who could still argue that there are lags in human learning, and organizational form, which could account for the observed delay in productivity benefits from IT investments. On the other hand, this assumes that at some point managers "catch up" and learn how to do it. But this is unrealistic looking at the history of hardware and software innovation in the 80s and 90s. Change is continual, constant, large scale, and framebreaking through much of this period. Managers may never really catch up. By the time they have learned, a new technology comes along to make the old learning less valuable.

<sup>4</sup> Along these lines the Brynjolfsson and Hitt (1993) data is remarkable. They claim that their Cobb-Douglas production function accounts for 99% of the variance in output in their sample of

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380 firms. Generally, these high levels of R<sup>2</sup> are attainable only in samples of restricted variance. Their finding suggests that there really is no need to take into account management or organizational differences among organizations when examining productivity. Yet this finding is contrary to many others which find management and organizational factors very important, even contrary to their own conclusions that variations in historical period, and management learning are important factors in understanding productivity of IT investments. This is not to deny that on balance this study is the best in terms of data and modelling, just that the findings are remarkable.

<sup>5</sup> In part this may be because the IRS output variable (forms processed) already accounts for increasing complexity in tax law and regulations. One measure of increasing complexity of work for the IRS is the number of forms it has to process. New laws and regulations spawn new forms. At the FBI, arguably, the complexity of work (output variable of fingerprint processing) has changed little in twenty years. At SSA entitlement programs have grown significantly, as have the complexity of individual cases, although this has had little effect on OASDI (the old age retirement program) which is the largest program administered by SSA.

<sup>6</sup> All the models were estimated using the SAS REG procedure (SAS ver 6.08). Clearly all of the models have good F-statistics and R Squares. The analysis includes both the unit betas (listed under "Parameter Estimate") and the standardized betas (listed on the far right under "Standardized Estimate").

<sup>7</sup> First there are some issues about the adequacy of the model that we would like to discuss. Although workload and employees appear on both sides of the equation, they enter the productivity (LHS) in a non-linear way. The simple correlation statistics for these two variables are reported in Table 1 and it can be clearly seen that these variables do not have a uniform impact over all three agencies.

Second, the data was examined for collinearity and other problems. Collinearity was not a major problem. The condition index run from 49 to 72, which indicates that there is some collinearity. However, it is well below 100, the level at which excessively inflated variances occur (Belsley, Kuh and Welsch, 1980).<sup>7</sup> However, the variance inflation factors were examined but were severe only for IRS. (IRS has sufficiently large collinearity problems that no variables were entered when using the stepwise selection option.)

Third, from the Durbin-Watson test, it is clear that serial correlation is present in at least the IRS and FBI models. [For three parameters and N=21 the 5% level of significance the lower limit of D (accept the hypothesis of serial correlation) is 1.03 and the upper limit of D (reject the hypothesis of serial correlation) is 1.67. At the 1% level of significance, D(1)=.80 and D(u)=1.41. Thus, serial correlation is probably present for the FBI and IRS and indeterminate for SSA.]

The primary problem with positive serial correlation is that it reduces the estimated standard error which in turn causes the reported t-values of the parameters to be too large. Since the agency with the most severe case of serial correlation (IRS) is also the agency in which MIPs are already statistically insignificant a refinement was not felt warranted.

Finally, it is possible to "cure" most of the defects of these regression estimates by a variety of legitimate statistical techniques ranging from introducing dummy variables at places where the data series had major changes (e.g. the FBI in 1977, IRS in 1981), adding AR(1) corrections, and

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selecting only variables that would improve the fit (R-sq.) . All of these techniques were applied, however, none of these techniques changed the overall results about the varying effects of computers on productivity in these three agencies: increases in installed computer capacity, as measured in MIPS, increased productivity in the SSA, was related to a smaller increase in the FBI, and had essentially no effect on productivity at IRS.