A. INFORMATION TECHNOLOGY WORKERS IN THE KNOWLEDGE-BASED ECONOMY

by

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Even the most casual observer must admit that information technology is an increasingly ubiquitous presence in the developed economies. In the past 15 years, it has transformed the way we process words, analyse data, manage businesses, and communicate with our colleagues. In the years ahead, it is likely to be key to similar transformations in health care, education and commerce. In the course of this transformation, the national boundaries that have defined labour markets, capital markets and cultures are becoming blurred. The Internet has become a source of information and misinformation that can be communicated and responded to in nanoseconds. The world is demonstrating a voracious demand for information technology and an enthusiasm for the transformations it enables. Along with this demand goes a commensurate demand for the workers who are engaged in creating, developing, managing, and maintaining information technology.

The National Research Council is in the initial phases of a study that will examine US workforce needs in information technology (IT) over the next ten years and establish a common base for national discussions. It will describe the range of industries in which IT workers are employed (in the US or abroad), the types of jobs held, and the skills and education needed. It will profile the current IT workforce, including older workers, describe the market demand for IT workers, and examine the availability of both domestic and non-US workers. Looking to the future, the project will explore the capacity of the US educational system and of employer training programmes to produce qualified workers, as well as the feasibility of meeting labour needs from abroad. This paper is an initial exploration of some of the data and economic concepts needed to conduct that study.

The paper first examines three approaches to a definition of the IT workforce -- by industry, by occupation, and by educational training -- and presents how many there are by each definition. It then looks at the problems of forecasting labour demand when the technology that labour produces is changing rapidly. While avoiding the issue of whether there is a shortage of IT workers, it finally looks at sources of additional workers for the IT labour force and discusses data collection needed to lead to more informed policy decisions.

What is IT and how many people are employed at it?

With the current national statistics, there are three approaches that may be taken to defining the “IT sector” and those who work in it. They are:

3 . The views expressed herein are those of the author alone and not of the National Research Council.

1. *Industry-based.* The fundamental question here is: which industries are to be included? One industry-based definition of the information technology workforce would include: those businesses that produce software, provide online services and Internet access, supply computer programming and software development (SIC 737), that manufacture computers, their components and peripherals (SIC 357), that produce or sell communications services and equipment (SIC 367, 361, and 483), and that provide systems analysis services or data processing education, (SIC 8742 and 8243) (ITAA, p. 37). This is a very broad definition, however, and many sources limit the definition of the IT industry to SIC 737. (GAO, 1998—p. 5). Both the larger and the more narrow industry definitions include firms that employ many people who support the industry but are not directly involved in creating, developing, managing, and maintaining information technology. On the other hand, both GAO and ITAA exclude workers in IT occupations in other industries. By the narrow SIC 737 definition, employment in the IT industry more than doubled in the US from 628 600 in 1987 to 1.34 million in 1997. The ITAA report estimates that more than twice as many core IT employees are employed in non-IT companies as in SIC 737 companies. (ITAA, p. 9)

2. *By occupation.* The distinction between counting IT workers by occupation and counting them by industry is shown in Figure 1. Many more workers say that they are employed in IT occupations than are employed in IT industries. More concrete data may be obtained from the Bureau of Labor Statistics Industry/Occupation Matrix (as reported by Ellis and Lowell I. p. 4). In manufacturing, for example, only 122 000 of 268 000 who say that their occupation is in IT are employed in clearly identifiable computer-related industries. In the service sector, which employs a preponderance of IT workers defined by occupation, only about 40% of the one million IT workers by occupation were employed in the computer and data processing industry.

   Another approach would rely on an occupational definition enumerated through surveys of households and individuals conducted as part of the Current Population Survey of the US Census, or collected as part of the Scientists and Engineers Statistical Data System (SESTAT) of the National Science Foundation. (Ellis and Lowell, Veneri). “Core” IT occupations are usually defined as computer scientists, computer engineers, and systems analysts. There is debate as to whether programmers should be included as a fourth core occupation. They certainly should be, under our broad definition. Without programmers, Ellis arrives at 1.5 million IT workers in 1998 which becomes 2.2 million if programmers are included. These are shown in Figure 2. Inclusion of programmers is an important issue for policy, since the narrow definition gives rise to descriptions of soaring demand, while the broader definition reflects a much slower rate of increase and may actually turn to decline once Year 2000 fixes are complete.

3. By education. A third approach is to count people who have been educated in the core IT fields. The annual production of degree holders in computer science is shown in Figure 3. Baccalaureate production reached a peak in 1986 and then declined, at least until 1997. Since IT employment has been growing, there must be sources of IT workers beyond conventional degree programmes. In fact, only 41% of those employed as computer scientists, computer engineers, systems analysts, and programmers in 1995 had received a baccalaureate degree or higher in computer science or computer engineering. Another 19% had received a degree in some other engineering field (Ellis and Lowell II, p. 1). The next largest source was social

science, with 8%. Thus, tracking core IT degrees alone will provide a misleading picture of supply.[4.]

The SESTAT surveys reveal yet another difficulty in tracking IT workers. Different kinds of computer employment draw on graduates from different fields. The situation in 1997 is shown in Figure 4. About one-quarter of those who identify their occupation as systems analyst and more than one-quarter of information systems scientist and "other" do not have a degree in either science or engineering. Further, in the computer science intensive fields where there was a relatively low proportion of non science and engineering graduates, the percentage of those with computer science degrees declined between 1997 and 1995.

Is there a shortage of IT workers in the United States?

The rapid rise in employment of workers in computer specialties evident in Figures 1 and 2, combined with the downturn in degrees shown in Figure 3 would suggest that shortages of IT workers might be emerging. If this were the case, we would expect to see rising salaries for new entrants. Salary offers for baccalaureate candidates in the IT fields are shown in Figure 5. In constant dollars, these have been rising steadily since 1995 in all fields.

In addition to training, there are options available to employers, such as opening branches in low wage countries, thus keeping salaries down, even in the face of rapidly increasing demand. It may be that, by looking at salaries for US graduates alone, we are ignoring what is in fact a global supply of skilled IT workers.

Possible evolution of demand for IT workers

Given the slipperiness of defining the current IT workforce in the United States, it is very difficult to forecast future demand for IT workers, let alone know whether public policy should be directed toward increasing the supply. Some factors that may influence the evolution of demand are listed below.

Industry structure. Every day brings news of changes in industries that will have an impact on IT worker demand. The long-heralded convergence of communications and computing is finally occurring. As information technology equipment has become ubiquitous so has the need for standards so that the products produced through IT can be shared and widely used. The apparent tendency toward increased concentration in the design and use of operating systems and applications languages is an example of this standards-driven evolution. Mergers and acquisitions typically result in job loss as the partners learn to manage the combined business more efficiently. On the other hand, once standards are set there may be a proliferation of down stream firms innovating to that standard, when earlier such ventures would have carried the additional risk of choosing the wrong standard.

Productivity and wage gains from IT. Some studies (Autor, Katz, and Krueger, 1997) have found that increases in the use of computer technology have been associated with a general rise in the relative return to higher education and demand for highly skilled workers. It would now appear that the "productivity paradox" in which productivity growth seemed unaffected by large investments in information technology

4 . It should be noted that there is a generational problem here. Formal computer science degree programmes became widespread only in the late 70s, so part of the explanation of non-computer trained people in computer-related fields may reflect this change. This observation would not explain the growth in IT employment while degrees granted in computer science are declining in the years since 1985.

has been resolved. Microeconomic studies (Brynjolfsson and Hitt, 1998) have found a strong association between investment in IT capital and revenue increases. At the macroeconomic level, the United States is experiencing levels of productivity growth higher than any seen in the past 40 years. Economists are now taking a new look at how IT changes the nature of work within the firm. The implication of these increases in productivity for demand for IT workers is less clear. The lag between investment in computer-related capital and improvement in productivity suggests that technology adoption is a slow process. Rapid technical change may actually hamper the organisational changes necessary to the productivity-enhancing use of IT.[5]

Rates of technical change in IT itself. Computing power and the degree of connectivity of computers has been growing exponentially for the past 20 years and no end is in sight. Each jump in power and connectivity has given rise to a need for new applications. IT personnel who work on long term projects find that their skills rapidly become obsolete and that constant retraining is necessary in order to compete with new hires who are expert in the latest technology. It is not clear that IT employers provide that training. Rather, anecdote suggests that IT workers change employers often and established IT firms absorb successful start-up firms that have been able to capitalise on the latest technology. For non-IT industries, one way of dealing with the difficulty in finding IT workers is to outsource the development of computer applications to specialised firms. This increase in specialisation may also limit demand for IT-trained workers.

Research is needed to find out about the career paths of IT workers. It means one thing if IT workers move out of IT in order to manage IT development. It means something very different if IT workers leave an IT occupation totally and abandon IT-related work because their skills are irrelevant to newly developed technology.

Will the IT work of the future be done by IT-trained workers? There seems to be no end in sight to the growth of IT-using applications. Current perceived shortages in IT personnel could give rise to a number of possible responses only some of which would justify public investment to increase IT worker supply. We need to develop data-based models of the substitutability between IT workers and software. As software becomes user-friendlier, tasks that used to require programming skills today may simply require educated users in the future. This does not mean that those skilled in the technical aspects of IT will no longer be needed. It does mean that the demand for IT personnel may not grow as rapidly as the demand for IT itself.

Data needs to track the evolution of employment in a knowledge-intensive economy

The reader will note that I have discussed the demand for and supply of IT workers without discussing the evolution of the "knowledge-based" economy. As IT becomes increasingly ubiquitous, that term will become redundant. It will simply be "the economy." In the meantime, however, we need to track the evolution to the knowledge-based economy and we know that those who create, develop, manage, and maintain IT play a key role in that evolution.

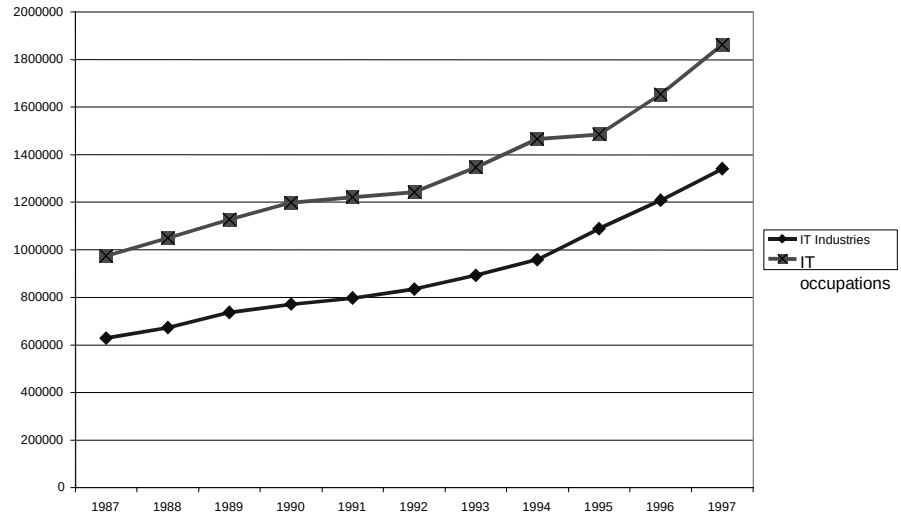
Two OECD documents provide a useful framework for data collection to understand what is happening to information and communications technologies and the workers that make it possible. The OECD *Canberra Manual* (OECD, 1995) in Chapter 4 presents a helpful framework to define stocks and flows that could be used both nationally and internationally to examine the dynamics of the IT labour market. More recently, the OECD has produced a succinct paper on *User Needs and A Proposed Set of Core Tables* to track information and communications technologies (OECD, 1998) which is a good first step. It would be difficult, however, to apply these approaches to US data. In addition to obtaining agreement on taxonomy,

5. See, for example, P. A. David (1990) on past introductions of new technology.

it is likely that the problem in developing meaningful data on IT workers that is comparable across industries and countries is to create these taxonomies with some flexibility. We need to agree on some fairly basic concepts: what is IT? Who is an IT worker? Are there IT career paths? Do IT workers receive common sorts of training, either formally or informally? Then, we need to create a system that can monitor a rapidly changing technology. The basic question is: how do we make a swiftly evolving technology sit still long enough to develop a consistent set of data concepts?

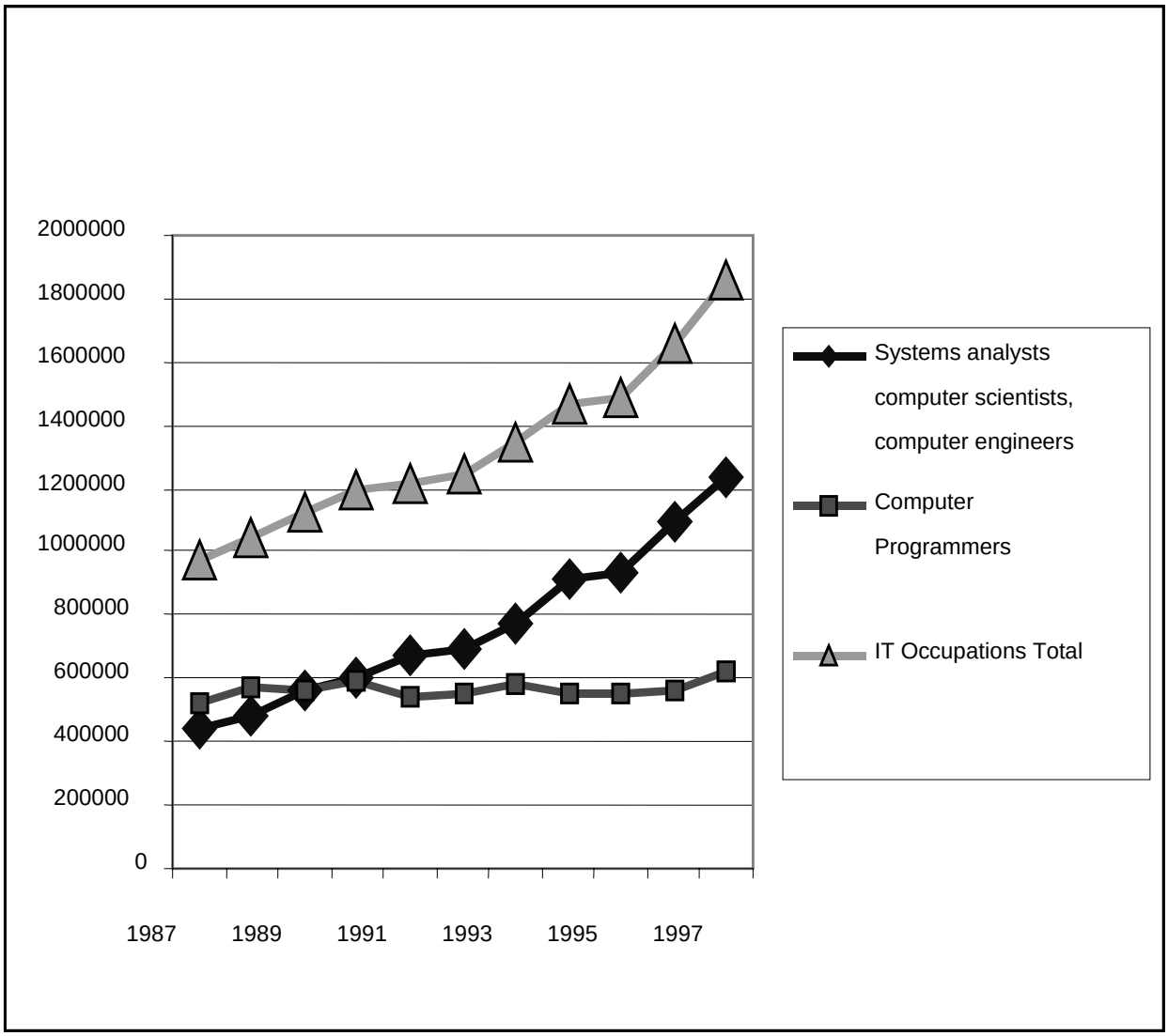
Why is this important? We have a set of data collection concepts that are appropriate to industrial economies. If IT is the key infrastructure in a world economy that is increasingly knowledge-intensive, we need to develop appropriate forms of measurement -- of output, input, and the organisational structures that change one into the other.

Figure 1. Information Technology Employment



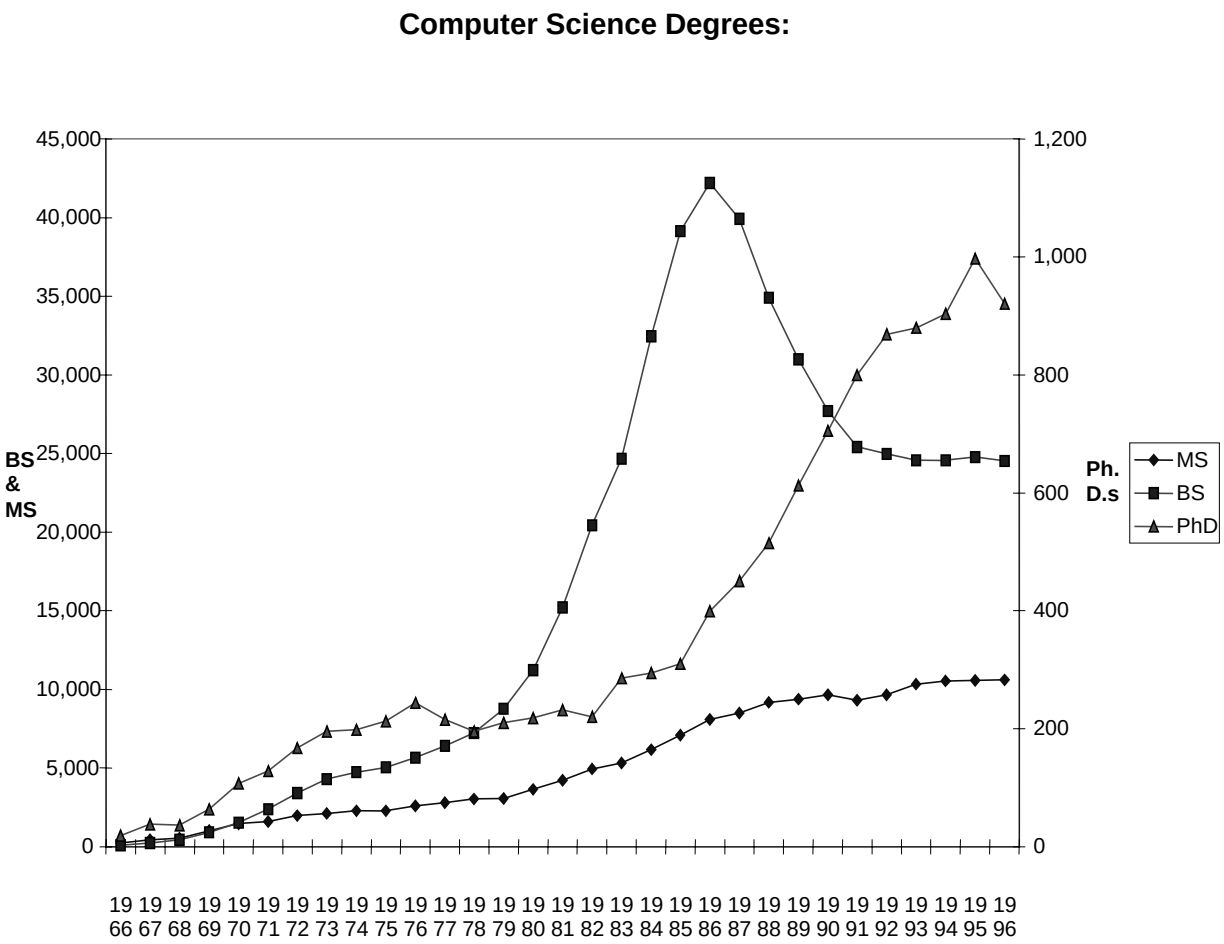
Source: CPS and CES data as reported in GAO, p. 17.

Figure 2. Information Technology Employment by Occupation



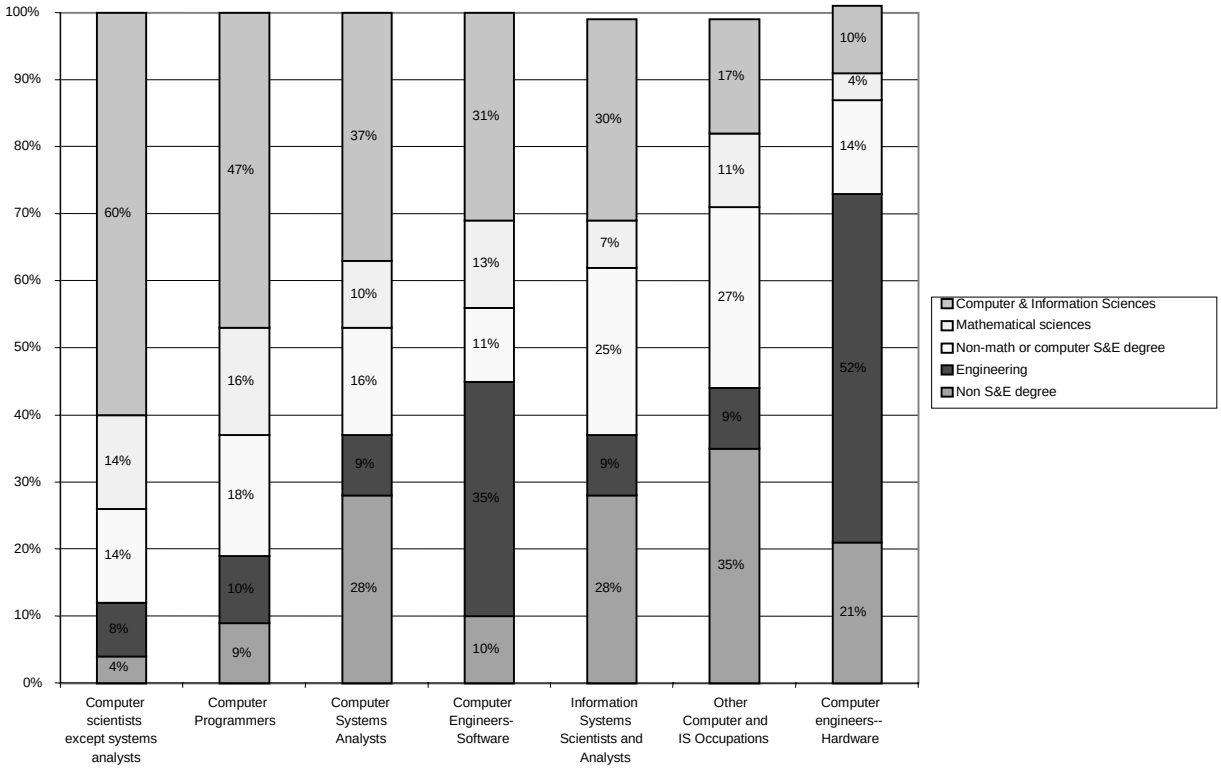
Source: CPS data reported in GAO, p. 17.

Figure 3. Degree production in computer science

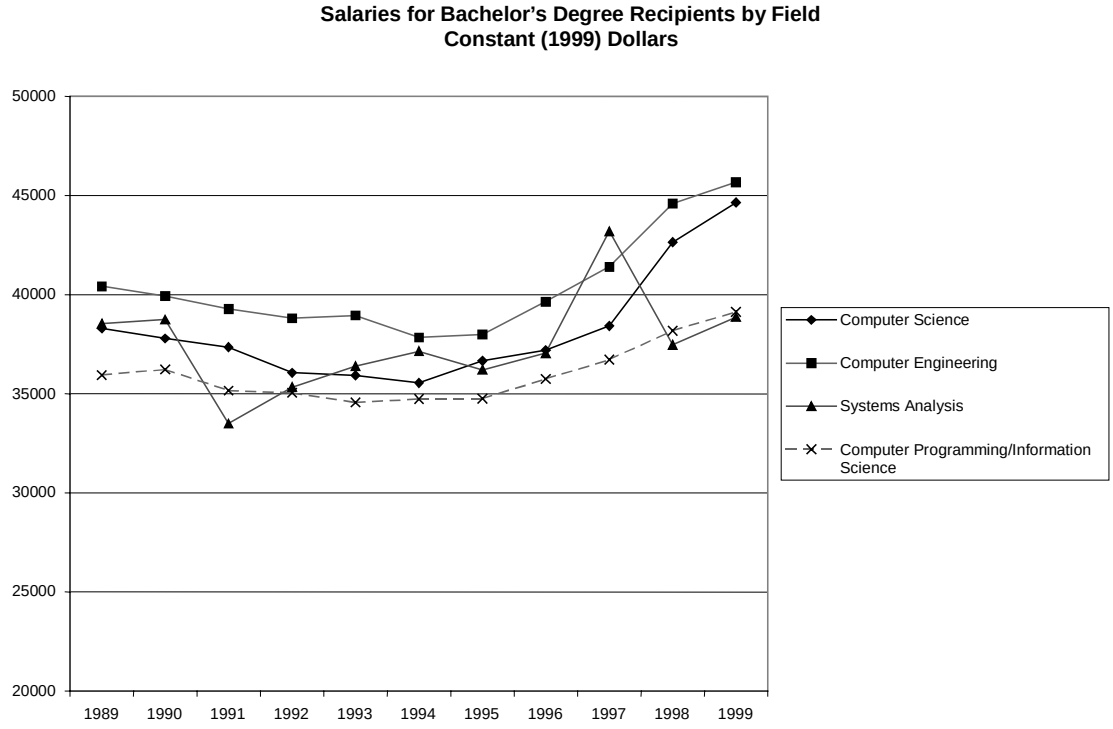


Source: CPS data reported in GAO, p. 17.

Figure 4. Occupation by Degree



Source: Veneri, p. 50.



Source: National Association of Colleges and Employers. 1999 Data through August.

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