3

Characterizing the Workforce Problem

3.1 FRAMING THE PROBLEM IN CONTEXT

Issues related to the IT workforce are controversial. To better understand the issues at hand, it is helpful to start with what has become the most common formulation of the problem:

1. IT employers of all kinds report having considerable difficulty in hiring workers for their open IT positions.

2. A shortage of IT workers is inferred from these difficulties.

3. Remedial actions are taken and/or proposed to increase the supply of IT workers.

There is much about this common formulation that is useful and valid. But each element of the logical chain must be scrutinized carefully. At the end of careful analysis, a much more nuanced and qualified picture emerges.

The third point concerning remedial actions is the subject of Chapters 6 and 7. Note, however, that the appropriateness of any given remedial action depends also on how one sees the origin of that problem, and the intent of this chapter is to focus on the first and second propositions.

3.2 REPORTS OF DIFFICULTY IN HIRING

The reports of IT employers that have considerable difficulty in finding workers for their open IT positions are based on Large numbers of vacancies,1

High turnover,

Long times to fill positions, and

Low unemployment rates for IT workers.

While the committee believes that employers are accurately reporting their difficulties in hiring, these reports must be framed against a number of important contextual factors. In particular, high turnover rates and long times to fill positions requiring particular skills mean that significant vacancies will occur even if the supply of qualified workers is equal to the demand for them.

Perhaps the most important consideration is the definition of a vacancy. The number of vacancies is sometimes used as a measure of the difference between supply and demand. But vacancy counts suffer from a number of problems. For example, data sources are not reliable. IT employers are increasingly turning to advertising job openings on the Internet. To the extent that vacancy counts are based on the amount of help-wanted advertising done in print (and if each help-wanted print ad represents one real open job), vacancy counts will understate the actual number of vacancies. Conversely, the lack of a posted vacancy may not indicate the lack of a position. Many IT employers have stated that they would be willing to hire an outstandingly talented individual even if no opening were immediately available, because s/he would be regarded as a strategic asset. Furthermore, advertised positions may not reflect immediate hiring needs, but may rather be posted in order to speed up hiring anticipated in the future (so-called "evergreen" positions for which IT employers are always recruiting).2 Or, advertising may reflect positions with particularly high turnover. Posted ads may reflect jobs that are contingent upon funding, for example, or on the presumed outcome of certain decisions that are out of the control of the immediate hiring manager.

A conceptual source of difficulty with the notion of "vacancy" is the fact that the number of jobs that need" to be filled is not necessarily a well-defined quantity. By changing production modes, improving productivity, and so on, a firm may be able to do the same work with fewer workers. (This subject is addressed further at the end of this chapter but can include such measures as reorganizing workers into teams, improving management, organizing work and training workers to improve productivity and product quality, and using automated tools.3)

A second major factor is the variation in hiring difficulty by type of worker sought. Demand is particularly high for some types of IT workers and less high for other types. In the aftermath of the Y2K programming problem, demand for COBOL programmers is declining, while demand for e-commerce specialists and Java programmers is increasing. In general, the time to fill a position varies with the position, but not surprisingly, positions requiring workers with "hot" skills take longer to fill. And, in the absence of data across the different types of position in the IT sector and in IT-intensive industries, advocates often make statements that imply uniform difficulty in finding workers. While an undifferentiated approach does not necessarily provide a misleading description of tightness in the market, policy remedies that are premised on the assumption of homogeneity may be misdirected.

Finally, the variation in patterns and severity of difficulty experienced by individual employers is considerable, although the committee has not encountered an IT employer who has said that he or she has no difficulties in hiring. For example, the committee has heard reports of turnover rates--a contributor to vacancy rates--that vary from 5 percent to 50 percent per year, as against a national average rate of 11.7 percent per year for non-IT workers (Box 3.1). High turnover in a single job can result in an inflated number of vacancies. Consider, for example, a company of 100 employees experiencing no growth and with a turnover rate of 10 percent per year and an average time to fill a position of 6 months. This company will create five vacancies over the course of the year without an increase in the demand for IT work.

With all that said, it is possible to make a rough quantitative estimate of the vacancy rate. If the vacancy rate V is defined as the number of jobs open, measured as a fraction of the workforce (i.e., open jobs divided by the number of jobs in the workforce), the following relationship can be used to estimate V:

$$V = (T + G) \times F,$$

where T is the rate of turnover (measured as percent of workforce turned over per year), G is the rate of net of growth in employment in the industry (measured as percentage of growth per year), and F is the average

time to fill an open position (measured in years).

As described in Section 7.2, the Bureau of Labor Statistics (BLS) estimates a growth rate in Category 1 IT professions of about 8 percent per year. Joint Venture: Silicon Valley Network indicates a value for F of 3.7 months for "high-tech jobs" and further estimates that the turnover rate in Silicon Valley is twice the national average.4 The national turnover rate for all workers is about 14 percent.5 All of these numbers give a vacancy rate of about 11 percent in these IT professions, if the conditions that characterize the Silicon Valley IT workforce obtain nationally. But, of course, they do not--the IT labor market is much tighter in Silicon Valley than elsewhere--and, as noted in Chapter 2, the majority of employers of Category 1 IT professions are not IT-sector firms (and not in Silicon Valley either).

Note also two important characteristics of this model:

Turnover and growth are portrayed as independent parameters. For the purpose of estimating vacancy rates as a function of turnover and growth, this is a reasonable portrayal. However, in fact turnover and growth are not likely to be independent of each other; that is, increased growth rates may well contribute to rising turnover rates as well. Such pressure arises from the fact that a worker may well leave a job in search of higher compensation--and in times of high growth in the IT sector and/or in IT-intensive industries, higher compensation may well be easier to find.

In this model, vacancies due to turnover are three times the vacancies due to growth (i.e., 24 percent turnover per year divided by 8 percent growth per year). Workers who leave one position are available for another one. Put differently, if turnover could be reduced, say by a factor of 3 (from 24 percent to 8 percent), the vacancy rate would be half of what it currently is--a rate that would surely result in less concern. As noted above, high growth may also lead to higher vacancy rates, but because workers may leave a job for reasons other than higher compensation offered elsewhere, employers have a variety of nonfinancial as well as financial options for reducing turnover.

A more refined model separates out the IT sector (employing about 25 percent of the Category 1 IT professionals) from the IT-intensive companies (employing the remainder). For this latter group, estimating the rate of employee turnover T as 20 percent per year, employment growth G as 8 percent per year (per BLS), and position time-to-fill F as 2 months (1/6 year) yields a vacancy rate of 5 percent for the workforce of the IT-intensive companies. Assuming that the Silicon Valley calculation for vacancy rate above is valid for IT-sector companies in all geographic regions (which it is not), a composite vacancy rate of about 6 to 7 percent is indicated.

3.3 THE INFERENCE OF A WORKER SHORTAGE

Accepting that most employers are indeed having some nontrivial difficulty in finding workers for their IT jobs, it is another conceptually distinct step to infer that there is a shortage of IT workers. An employer sees the workforce issue from the perspective of an individual firm. From this perspective, what matters is how many jobs are unfilled and how hard it is to attract workers to fill those jobs. But "shortage" is a concept that applies more broadly to the entire universe of firms that use IT workers and compares overall supply with overall demand for these workers. Thus, the relevant question is the extent to which the latter can be inferred from many individual employer reports regarding their difficulties.

Furthermore, part of the issue is terminological--the term "shortage" has many emotional connotations, and there is no uniformly accepted definition of the term among economists, to say nothing of common usage in discourse among employers. (Box 3.2 provides several definitions that have been presented to the committee in various forms.)

3.3.1 The Overall Labor Market

It is important to frame any discussion of shortages in the IT labor market in the context of tightness in the overall labor market. The labor market is tight across the entire economy, not just in IT. Thus, individuals (incumbent workers, those entering the labor force, and those that may leave the labor force) have many more options available to them than when the overall labor market is more slack. Therefore, individuals who might be motivated to move into IT for economic reasons have many other fields in which they may work productively. (Of course, tightness in the overall labor market depends on the state of the economy, now in an unprecedented tenth year of expansion. It is anyone's guess when the economy will experience a downturn but such a downturn would inevitably affect analysis of the workforce situation.)

Note also that tightness in the labor market for IT workers is felt the world over (Box 3.3).

3.3.2 The Size of the Applicant Pool

The size of the labor pool available for, and willing and qualified to do, IT work is a central issue in assessing the balance between supply and demand. Perhaps the most critical point is that the size of the relevant labor pool is not fixed--many factors affect it (e.g., compensation and wages, employer willingness to provide training for new hires6). But there is no direct measure of this pool, and much of the controversy about tightness in the labor market involves just this point.

The number of applicants for an open IT job is often cited as an indication that there are large numbers of skilled workers currently available.7 However, most individuals seeking employment in IT apply for multiple jobs. From the job seeker's perspective, it makes sense to send out many applications, to increase the likelihood that a promising contact will be established. The job seeker may also apply for jobs for which s/he is only marginally qualified, or even unqualified, on the theory that a high probability of rejection is better than the certainty of rejection if the individual does not apply at all for a given job. And even individuals who are employed may be "testing the market," if nothing else to maintain an understanding of trends in the sector in which the job seeker is interested and knowledge of his/her market worth.

Furthermore, the trend toward multiple applications has been fueled by the ease of posting resumes on the Internet. The use of electronic resumes and Internet-based recruiting is increasingly common in many sectors of the economy, and is especially common in the IT sector. The number of job-related Web sites is growing rapidly, and the number of resumes posted already runs in the millions (4.9 million electronic resumes were posted in 1999, and this figure is forecast to grow to over 16 million by 2002).8 It is not unusual to receive hundreds or thousands of resumes in the process of filling desirable IT jobs.9 As a result, while an individual employer may in fact receive many applications from different individuals, a group of employers may be receiving applications from the same pool of applicants, and so the size of the overall applicant "pool" is not as large as it might appear extrapolating from the experiences of individual employers.

Analysts also sometimes point to the number of individuals graduating yearly with computer science or related degrees and to the magnitude of layoffs in the IT sector. In the first case, the fact that many IT occupations--especially in Category 2--do not require significant amounts of formal IT training suggests that the number of computer science (CS) graduates produced yearly is not a good indicator for the labor supply as a whole taken across all IT occupations. On the other hand, it is difficult if not impossible to determine how many non-CS graduates have the skills to enter the IT workforce immediately.

As for layoffs in the IT sector, they are considerable. For example, the outplacement firm of Challenger, Gray, and Christmas reported that, over the first 11 months of 1999, the computer industry had laid off 60,000 employees.10 This number is equal to approximately 3 percent of total employment in the "computer services" industry, as defined by the Bureau of Labor Statistics.11 Whether these individuals constitute a ready, immediate, and usable source of supply is unclear. On the one hand, they may not necessarily have IT skills, because, like all companies, IT firms employ many support staff, clerical staff, building maintenance staff, and others. And, even if those laid off are technical workers, they may or may not have the skills needed by

employers that are growing and hiring. On the other hand, some organizations such as SAIC and the Communications Workers of America have demonstrated that to a certain extent, retraining of laid-off "employees" (i.e., ex-military personnel) to undertake IT work can be possible. The supply of "qualified" workers made available by layoffs may well depend on the efforts that are undertaken to enhance their technical skills.

Finally, the size of the relevant applicant pool depends greatly on policy decisions that regulate the number of foreign IT workers who may work in the United States. These include skilled IT workers on H1-B temporary visas (who must have at least a bachelor's degree), permanent immigrants, and foreign students graduating from U.S. colleges and universities.

3.3.3 Skills Shortages Versus Worker Shortages

If there is a "shortage," what is in short supply? In the common formulation described at the start of this chapter (and most often articulated by IT employers), the shortage is one of workers. But in the IT workplace, not any warm body can be an IT worker, nor are IT workers interchangeable with each other. Attention must also be paid to the ability of putative workers to do IT work. Thus, any shortage in fact refers not to IT workers but to qualified IT workers--with all of the discussion and nuance that relates to the definition of "qualified." Specifically, critics of employer practices believe that the job definitions used by employers overstate or exaggerate the qualifications that are actually needed to perform the work required in job openings. Further, they argue, the employer demand for a "perfect" fit between an employee and a posted job opening creates artificial difficulties in finding human resources who would be able to do the work of a posted job with only a "little bit" of training.

3.3.4 Compensation

Compensation must figure prominently in any discussion that relates the supply of labor to demand. The basic economic model is the following: Demand for labor relates the number of jobs that are available as a function of the compensation that employers are willing to offer for those jobs. Supply of labor relates the number of people willing to work as a function of the compensation that employers are willing to offer. When demand exceeds supply in a particular occupation, compensation tends to rise relative to compensation in other occupations that require similar education, effort, and working conditions. Rising compensation attracts into a field more people who are willing to work (increasing the current supply), decreases demand for those workers, and signals to those capable of being trained to begin studying for these jobs (increasing the future supply of new entrants).12

To the extent that compensation does not rise, the signal is not sent to labor market entrants, and thus the potential labor force for these occupations is sparser than it would otherwise be. Potential workers seeing rising compensation in IT will move preferentially into the IT field by preparing themselves by education (in the case of students selecting courses of study13) or by retraining in the appropriate disciplines for IT work (in the case of workers in other occupations). Typically, the greater are the incentives provided by employers to induce workers into the occupation of interest, the quicker and greater will be the response by potential entrants. This phenomenon works to restore equilibrium, and over time, a new equilibrium is reached at a new intersection of the labor supply and demand curves (with higher compensation and more workers).14

As a rule, rising relative compensation is seen by economists as the most reliable indicator of tight labor markets or shortages. As noted in Chapter 2, Current Population Survey (CPS) data indicate average annual wage increases in constant dollars of 3.8 and 4.5 percent for computer programmers and for computer systems analysts and scientists, respectively, during the period from 1996 to 1999, rates somewhat higher than the average annual wage increases of 3.2 percent for professional specialty occupations.

Does such an increase in wages over this time period warrant a conclusion of an IT labor shortage? Because there is no universally accepted wage indicator of shortage, this question does not have a definitive

answer. A common view held by those who do not believe that there is a "real" labor shortage of IT workers is that employer difficulties in finding suitable workers stem primarily from an unwillingness to invest more in human capital, both in the form of higher salaries and other compensation and in the form of training (and retraining). They further believe that employers' desires to minimize labor costs lead them to favor younger workers and foreign workers because their services can be acquired less expensively than would be the case if older workers and/or permanent U.S. workers were hired.

While the data indicate an increase in wages for IT workers in the late 1990s when economic theory would predict one, a historical perspective is obtained by comparing this increase to increases for other occupations at a time of strong demand for new workers. For example, demand for nurses was strong during the late 1980s. The committee's analysis of data from the CPS indicates that from 1987 to 1990 the average annual increase in hourly wages for nurses was 29 percent higher than that for women in professional specialty occupations. The average annual increase in income for computer systems analysts and scientists was 41 percent higher than that for individuals in professional specialty occupations from 1996 to 1999, while the average annual increase in income for computer programmers was 19 percent higher than that for individuals in professional specialty occupations during that period.

In any event, there are several practical difficulties with using wage data to determine the existence of a labor shortage. For example, raising wages may be one of the last things employers do to respond to a shortage,15 so the evidence for tightness in today's labor market may not be reflected in the data cited. An employer may be reluctant to raise wages for incoming workers because of concerns over equity and morale within the firm.16 Most serious, though, is the fact that BLS wage data are incomplete.17

In particular, BLS data on base wages do not reflect the complexity of compensation packages--they do not reflect variable pay such as project bonuses, hiring bonuses, overall company bonuses, or senior personnel retention bonuses. Respondents to the BLS questionnaire may--or may not--report total cash payments rather than wages, and there is no way to disaggregate these responses. Furthermore, because the wage signal of increasing tightness in the labor market is a trend of increasing compensation (implying comparisons over time), BLS data themselves cannot signal trends if cash payments other than base wages constitute a changing fraction of total compensation. Similar comments apply to stock options and equity stakes, which the BLS data also do not include, and which are also important elements of compensation in much of the IT sector and in some IT-intensive firms as well. Indeed, for individuals highly motivated by financial incentives, stock options and equity stakes are far more likely than wages to be the road to riches.

Some data on total compensation packages are provided by a private survey,18 which indicates that nonsalary cash awards and long-term incentives such as stock options range from 23 percent of total compensation (6 percent cash awards, 17 percent long-term incentive) for technical staff such as software design engineers, software operating systems engineers, and research scientists to 48 percent (6 percent cash awards, 42 percent long-term incentive) for managerial staff such as software engineer managers and research scientist managers. Further, data from this private survey, presented in Box 3.4, suggest that the growth rates in base salary for technical staff in the software sector are approximately consistent with the growth in wages as indicated in the BLS data. However, growth rates in total compensation are higher than growth rates in base salary by 40 percent (2 percentage points) for technical staff. (Technical staff are approximately those represented in the BLS job titles of computer scientist, systems analyst, and computer programmer.) In addition, Box 3.4 provides some evidence that growth rates in base salary and total compensation are significantly higher for managerial staff in the software sector than for technical staff. This information would suggest that tightness in the managerial labor market is significantly higher than tightness in the technical labor market.

The committee notes that the bias induced by the lack of data on nonwage compensation is likely to be larger for smaller companies where, at least until recently, many workers have taken equity stakes or stock options in lieu of greater base pay. Such a bias would tend to understate compensation for workers in this category, who tend to work in the smaller companies. By contrast, some larger, more established firms report increasing pressure to raise base salaries rather than stock options, indicating a different trend from that generally seen in the compensation pattern of small companies. Many new workers at the larger companies view the large gains in stock prices of the past as unsustainable and thus value them less as part

of the compensation package. Thus, at some very successful companies new entrants are demanding higher salaries, but total compensation may not be higher.

3.3.5 Time to Reach Equilibrium

When supply and demand are not in balance, labor markets will take some time to reach equilibrium. (Box 3.5 describes some reasons that markets may take a longer rather than a shorter time to clear.) But the argument that a labor market will eventually reach equilibrium is of little comfort to IT employers, who operate in a competitive and fast-paced environment (as described in Chapter 1) and are concerned primarily with the short term. In the short run, supply to employers as a whole is relatively inelastic, meaning that the number of workers willing to work at a particular wage does not change much when the wage is increased. However, employment needs must be met rapidly (on time scales of weeks and months, not years) if they are to be relevant to the business. How these needs are met in the short run, however, can have important implications for the long-term adjustment of supply.

In addition, economic theory predicts that there are some circumstances in which the demand for labor continually increases faster than the supply of labor, and the market does not even approach an equilibrium. In this situation, the problem is not necessarily that workers or employers cannot adjust; rather, the problem is that they do not adjust fast enough, or do not predict the future sufficiently well.19

3.4 THE COMMITTEE'S VIEW OF THE IT LABOR MARKET

Issues related to the IT workforce attract many advocates, who have different interests, objectives, and perspectives. It is perhaps the nature of an intense political argument that these various advocates spend a significant amount of energy in attacking the positions and views of those who disagree with them. Nevertheless, it is the committee's view that all of these parties have legitimate perspectives that can shed useful light on the relevant issues, even though no one party has a monopoly on the "truth."

The committee has chosen the term "tightness" rather than "shortage" for several reasons. First, there is no universally accepted definition of "shortage." Second, the use of the term "shortage" can imply a binary condition--either there is or is not a shortage. But the term "tightness" can encompass "shortage" as its limiting case--the condition in which employers find it impossible to find qualified workers no matter what they pay or how long they wait--and still account for the continuum nature of the phenomenon. Third, the committee feels that "tightness" is a broader and more encompassing term that does better justice to the complexity of the issue.

Thus, the committee's characterization of the IT labor market is the following:

Today, the IT labor market is tight, though the nature and extent of such tightness vary by employer, by type of IT work involved, and by geographical locale. The fundamental driver of this tightness is growth in the use of IT throughout a strong economy, a tightness that is significantly exacerbated by the currently low unemployment rate in the overall labor market.

As for the implications of the available wage data, they are consistent with the committee's characterization of the issue. BLS data show wages across the Category 1 IT professions rising more rapidly than wages for scientific and engineering occupations generally, but not at a dramatically rapid rate. This is consistent with some degree of tightness in the overall IT labor market, though it also suggests that extreme tightness does not characterize the entire IT labor market. But BLS data are highly aggregated, and indeed lump together many market segments within "core" IT professions. On the other hand, private market surveys do indicate much more rapidly rising wages in certain segments, for certain types of employers, and for certain specialties within these professions. Accordingly, these data suggest that the IT labor market is highly segmented, and that certain segments experience much higher degrees of tightness in the overall market.

3.5 SEGMENTATION OF DEMAND FOR IT WORKERS

The term "demand for IT workers" or "tightness in the IT labor market" masks nuances that are critical for understanding the IT labor market. Labor market dynamics are very different in different segments--and different enough that discussing the IT labor market in an undifferentiated manner glosses over important characteristics and features.

For example, growth in the demand for IT workers is not uniform across all IT occupations. Coarse as they are, BLS job projections through 2008 indicate the most significant growth in the demand for computer scientists, computer engineers, and systems analysts, with much less significant growth in demand for computer programmers.

A second distinction is the nature of the skills that are in demand. Today, Category 1 workers involved in the design and creation of software and hardware systems are in particularly great demand. Recent studies and field hearings of the committee also indicate tightness in labor markets for computer programmers experienced in applying Enterprise Resource Programs (ERPs) and object-oriented programming languages (e.g., Java). In addition to these workers, Internet specialists and workers experienced in e-commerce are in great demand, as are faculty to educate the next generation of IT workers.

The segments of greatest workforce demand vary depending on technology and trends in the industry, and these segments can manifest themselves rapidly with little warning. For example, the explosion of Web activity in recent years has created a huge demand for Web-savvy IT workers. The movement to "network computing" and applications service providers--while somewhat slower than the expansion of Web activity--is likely to lead to a large demand for IT workers who understand and are proficient in mainframe computing. Similar comments apply to skills required for using different types of software products. Using new packages or languages poses a problem of finding adequate numbers of trained workers because of lag time in training and education and lack of formal skill development systems, coupled the recent rapid expansion in these development and application areas. As a rule, emerging and broadly useful technologies create high and rapidly increasing demand for skills (and experience) with that technology. Shifts such as these in workforce demand cannot be anticipated with any precision (because the precise path of future technological developments is uncertain), but such shifts are bound to occur.

Another skill set in high demand is nontechnical skills in otherwise technically qualified people. These skills include communication and the social skills and ability to work in a team. These skills have become more important for a number of reasons. The technology has become more complex and more ubiquitous, especially in mission-critical applications, forcing system development to occur in a team environment; the needs of the end user play an increasingly important role in defining system performance requirements, forcing developers to better understand a user's needs (even when he does not understand them himself); and the methodology of development has changed in many cases, now emphasizing the use of cross-functional teams that must interact with each other.

Industry type also affects the types of skills in demand. For example, software development firms generally seek individuals with tool development experience. Furthermore, "brilliance" is in high demand among such firms, and individuals with extraordinary talent can make huge differences in the productivity and output of a team. By comparison, IT-intensive firms tend to seek individuals with experience in implementing applications and with a good understanding of the firms' core business.

A third distinction is demand for certain types of workers. In particular, IT-sector and IT-intensive firms have a very strong preference for workers with real-world experience in the work of interest to those firms. In some cases, experience with applying a certain technology is the requirement. In other cases, the essential skill is project management coupled with deep technical knowledge.20

A fourth distinction is geography. Tightness in the labor market can be exacerbated by local conditions. For example, the lack of affordable housing in the Silicon Valley area is a disincentive for potential IT workers to relocate there.21 (At the same time, many Silicon Valley firms capitalize on their proximity to other similar firms as a recruiting draw, offering the promise of exposure to the cutting edge of technologies

being developed by many firms there.) Tightness has also been acute in the Seattle area, given the large-scale hiring needs of Microsoft and a range of Internet-based firms and the apparent historical pattern of the Seattle region as a net importer of IT workers. Other metro areas, too, have had tight IT labor markets that have pushed firms to recruit nationally and internationally. For example, in Austin, the committee heard that strong job growth, and not turnover, was responsible for the region's tight IT labor market. One firm in this burgeoning high-tech area that was brought to the committee's attention had grown from 120 to 800 employees in 1 year.

Regional supply issues may also affect different types of workers differently. For example, systems development work tends to draw workers from a much more national market (with systems development personnel being more geographically mobile), while demands for network and systems administration work tend to be satisfied with labor recruited locally (from the local labor market and neighboring education and training institutions).

A fifth distinction is that the character of workforce demand is rather different for firms with different histories. For example, a start-up company generally faces a more uncertain economic future than does a well-established company. Employees at a start-up company may well receive smaller salaries than those they would be able to command at a more well-established company in return for greater degrees of equity stake.22 (Though more risky than compensation offered as salary, equity stakes are, of course, the workforce equivalent of the "lottery-win" potential offered by initial public offerings, or IPOs.) Thus, an individual's degree of risk tolerance and/or financial ambition influence the labor pool from which a start-up company can draw. More generally, smaller companies are generally less constrained on compensation than larger companies by personnel structures and conditions and requirements to maintain pay scales and equity. (An exception is large consulting firms, which are generally able to pass on labor costs and staff for short-term project needs, and thus can offer compensation packages in excess of what their clients can offer--example:

Peoplesoft implementation. Consulting firms also offer the opportunity to obtain a variety of experience and learn a range of skills, which is desirable for workers and increases their future market worth.)

Compared to larger, more established firms, small start-ups also tend to offer less regimented workplaces and the opportunity to work on technology frontiers. And because they are smaller, they provide opportunities for individuals to have a large impact that might not be available in larger companies. The flip side of smaller companies is that their workforces have less depth and less capacity to mitigate the impact of shortages--one open position has less impact on a project of 10 people than on a project of 3 people. Furthermore, a small start-up lacks an established market presence, and so the impact of workforce shortages on survival is more severe.

3.6 A PERSPECTIVE ON THE FEDERAL GOVERNMENT AND WORKFORCE ISSUES IN IT

Although the U.S. government's need for IT workers is not a primary focus of this report, the committee believes that the U.S. government is itself a major stakeholder because it, just like enterprises in the private sector, is becoming increasingly dependent on information technology. The following description of challenges facing government agencies is based mostly on a public session held February 29, 2000, in Fairfax, Virginia, with the committee.23

3.6.1 Competition with the Private Sector

Government agencies are severely challenged in recruiting and retaining talented information technology workers, particularly workers with newer technology skills and those at entry-level jobs. Government compensation packages (discussed in more detail below) and widespread government use of information technologies that are not at the leading edge of technology create disincentives for many people to take government jobs in IT.

As a result, most agencies are operating with high vacancy rates and experiencing high attrition rates in their IT workforces. For example, the Department of Defense is budgeted to operate with a combined IT workforce of approximately 60,000 and reported a current vacancy rate of 10 to 12 percent, with expectations that that figure will rise in the coming years. The Office of Personnel Management (OPM) believes that across the federal government, demand outstrips supply in the IT field. It has projected that between now and 2006, there will be approximately 37,000 positions to fill. This calculation takes into account new job growth, attrition, and retirements.

To date, government has tended to experience the highest degrees of labor market tightness for qualified professionals seeking entry-level jobs. A survey conducted for the Treasury Department noted that recruitment efforts were not netting younger workers, ostensibly with newer or more unique technical skills, nor were recruits coming from the private sector.24 For reference, in 1993, two-thirds of new IT hires at Treasury came from the private sector; that figure has shrunk to one in eight new hires. The federal government is churning its current IT workforce or promoting non-IT federal workers into IT positions. Those people coming into IT careers at Treasury are on average older than those who are already in those careers and have less formal training than those who are already in those careers. Treasury reported that it is trying to use the same tools and technologies that the private sector is using--Oracle, Peoplesoft--but there is an immense issue of a shortage of database administrators or security experts everywhere, which hampers federal recruiting efforts.

About half of the federal IT workforce will be eligible to retire over the next decade. For example, the Department of the Treasury has an IT workforce of approximately 9,300 employees (approximately 9 percent of the total federal IT workforce),25 with an average age of 44 years, and there are more IT workers over 55 years of age than under age 30. At the Internal Revenue Service, there are nine times as many IT employees over 55 as there are under 30. If the private sector keeps offering incentives to federal workers with particular IT skill sets to leave, the federal government is at serious risk of losing staff at a time when more and more members of the public are asking for greater access to information from the government.

Competition with the private sector is manifested in other ways as well. In particular, government representatives testified to the committee that private industry is often suspicious of the government's interest in achieving greater degrees of technological sophistication--especially since expertise and sophistication are needed to exercise proper oversight over IT contracts with the private sector.

3.6.2 Incentives

As noted above, IT workers are motivated by many things other than money. Nevertheless, government service pay scales appear to be a key barrier to recruiting and retaining IT workers. It is axiomatic that government cannot offer stock options or equity stakes that promise riches. But the civilian pay scale is also significantly lower than what IT professionals can command in the private sector. The bonus system consists of about a 1 to 2 percent bonus based on merit. In comparison, the NACE Web site listed 1999 starting salaries for computer science graduates at $45,000. At the Department of Defense (DOD), CS graduates are ranked at GS-7 step 4 or 5, about $32,000. Furthermore, the system is based on seniority, so the first person to receive a reduction-in-force (RIF) notice tends to be the most junior person on the payroll, who probably has the most recent technology education and skills.

On the upper end of the scale, Army research laboratories hire Ph.D.s who can command salaries of $60,000 to $70,000, equivalent to a GS-13 or GS-14. However, this practice can create a morale problem when other employees with 20+ years of experience who are not GS-14s learn of a new hire with little work experience being hired at a higher grade. Some branches of the service, such as the Navy, have developed strategies to be able to offer market rate to employees and incentive bonuses for working in undesirable locations or other hardship situations. The Army is doing pay banding, whereby it can offer a wide range of starting salaries, but again, morale can be adversely affected by these procedures. Furthermore, agency budgets often do not have enough money appropriated to cover the civilian pay of

people on board, much less vacancies, so agencies supplement with programmatic funds. This practice does not encourage funding bonuses or incentives, however.

The Office of Personnel Management has been asked to review IT jobs in government, particularly the classification of entry-level jobs to which the government would like to attract talent, as well as strategies to reward high-quality technicians with higher wages without obliging them to move into management. But this review has not been completed at this writing (August 2000).26

Some agencies have used retention incentives with some success. The Internal Revenue Service gave retention incentives of 10 percent of salary to about 900 of its Washington, D.C., area programmers. The immediate goal was to help through the year 2000, but it was seen as a strategy to retain a critical workforce, especially as a large proportion near retirement age.

In addition, testimony to the committee suggested that there are a number of nonmonetary incentives, both modest and elaborate, that might make the federal government more competitive with the private sector for IT workers. These included:

Interesting work. NASA realized that it did not have the traditional levers to attract candidates to its ranks. So NASA staff went to universities and spoke with graduate students and enticed them by telling them that they could come to NASA to do long-term research. This has been an attractive magnet, and NASA has been able to recruit young graduates.

Frequent-flier miles. Even such a modest perquisite as the right to accrue frequent-flier miles for personal use would help to reduce the irritations of federal service.

Flexible working conditions. Flexible scheduling, teleworking, flex time, flex place, and loaned computers are standard practice at many companies but are implemented on an ad hoc basis in the federal government. More systemic utilization of new business work models in place in federal guidelines could help to entice workers to join or remain in the federal workforce.

Tuition reimbursement. In the private sector, tuition reimbursement is a common perquisite for attaining a degree or getting certification, but the federal government is far less generous.

3.6.3 Recruitment and Retention Issues

Bureaucratic barriers and the inflexibility of a lethargic hiring system are another challenge to government recruitment of IT workers. Often, the time between when a position is authorized and when that position is offered is about 6 months, which is not competitive with the private sector. Good candidates will not wait this length of time.

The work of the federal Chief Information Officers (CIO) Council, composed of top CIOs across government, has prompted greater collaboration with colleagues in the human resources arena to talk about recruiting issues, problems, and concerns. For instance, online recruiting is a common tool, yet is a very small percentage of how the government seeks new candidates. OPM has acknowledged the challenges and remarked that new efforts were being implemented, such as IPAs, term hires, various arrangements with universities, and co-op programs to bring in students at a much younger age, as well as the new Federal Cyber Corps, proposed by the White House, whereby students' costs are covered in exchange for service to a government agency for several years. Part of the scholarship program includes funding for faculty development, perhaps through actual funding of positions and other strategies to support faculty development and retention at the university level.

3.6.4 Coping with Tightness

In the short term, most agencies deal with their difficulties in hiring IT workers by contracting and outsourcing work. This effort challenges agencies to develop better project management skills among the federal workers. The CIO Council has spawned the STAR program (Strategic Tactical Advocates for Results), in which agencies work not only with IT people but also with business people to bring better project management skills to the fore. A significant number of DOD personnel are civilian contractors--even deployable units contain civilian contract staff. NASA has concentrated its work on its core competency and has pushed the bulk of its operations outside the agency. This has freed people to concentrate on IT research rather than on operations. At the Department of Energy, Office of Science, three federal employees manage about 25 contractors who are completing redoing DOE's architecture.

It is worth noting that the U.S. government can employ only U.S. citizens for many IT jobs, and hence foreign workers are not available to it. Moreover, many IT jobs in government require the job holder to have security clearances, which are not usually available to foreigners.

Finally, the CIO Council and OPM have identified career development as a key component of attracting, retaining, and improving the people in the federal workforce. They have challenged all agencies to spend at least 3 percent of their total IT payroll on professional development of their IT workforce, and many agencies are complying. The CIO Council also discovered that management has a tremendous influence on individuals' satisfaction in the federal workforce, so the Council has recommended that OPM craft a program to develop better managers and supervisors to work with new IT workers, who likely have many nontraditional work styles.

OPM has identified a number of longer-term actions that focus on education and training. It will institute a training initiative that would leverage training initiatives already in place at different agencies and from the private sector to train the current IT workforce and to bring up the levels of competence, specifically in the IT security arena. OPM will also institute a high school awareness initiative, in which OPM will reach out to the high schools to increase awareness, in both educators and students, about IT security and to help promote entry into the IT profession and into government service.

3.6.5 Security

Security is a particular challenge within the federal government. From the perspective of those who testified to the committee, security had two components: security in the sense of protecting classified information and security in the sense of providing greater security for computer systems. On the former, some reported difficulty in attracting qualified employees into jobs requiring security clearances.

On the latter, NASA plans to capitalize on information assurance and security to advance its efforts to create a more paperless agency and its effort to do enterprise management. NASA operations and systems administrators are mainly contractors, and the concern at NASA headquarters is how NASA will obtain the right skills in such an environment. NASA IT workers not only need to know Cisco routers, but also must be experts in NT or another operating system, and must understand forensics and scanning tools. Work at NASA is complex, and finding people with the full suite of skills is challenging. NASA also needs senior management personnel who can oversee operations for IT security training.

The new Federal Cyber Corps program (mentioned above) was developed by OPM in direct response to the need for efforts to increase computer and infrastructure security. The Treasury Department has been successful in some areas that mirror the private sector, such as e-commerce, and pointed to the U.S. Mint, the Bureau of Engraving and Printing, and the Bureau of Public Debt Web sites that sell directly to the public as a prime example, but agreed that issues of privacy and security and authentication were still trouble spots. The latest rash of Web site sabotage (hacking of Amazon.com, eBay.com, and others) reinforced cyber security as the CIO Council's number one priority.

3.6.6 Concerns Expressed by Government Contractors

Contractors carry out a considerable amount of government IT work. Presentations to the committee from contractors indicated that in some areas government oversight of contracts has become counterproductive. Contract documents should focus on detailing functional requirements, but in many cases they are too specific as to how the work should be implemented. This overspecification discourages the innovative use of technology.

Contractors also reported that government agencies had become highly demanding in requiring specific skills and years of experience for each project member. Increasingly, government agency clients are requiring that their projects be staffed with personnel who have particular software and/or hardware skills, on the assumption that this will lead to faster and better project completion. Contractors hiring workers for such work are legally bound to hire on the basis of these contractually specified qualifications, regardless of whether or not they are in fact necessary for proper execution of the work under the contract. Given such requirements, there is less opportunity to "sprinkle" recent college graduates among highly experienced workers in project teams--the traditional way new hires at contractors gain experience.

Furthermore, the U.S. government--and specifically the U.S. government as represented by the contracting officers involved--generally insists as a contractual matter on approving individual personnel (in addition to specifying personnel requirements) to be hired under a project. A number of firms testified to the committee that U.S. government contracting officers had indicated to them disapproval of qualified job applicants from minority or other groups protected by antidiscrimination statutes. Yet as private employers, they are bound by all of the obligations imposed by such statutes.

Finally, contractors noted that agencies did not allow training of contract employees as a direct bill or as an allowable part of billable overhead unless the training was explicitly called for in the contract. This constraint discourages companies from maintaining the skills of their employees. Such provisions are a nontrivial disincentive to offering training for IT workers on these projects.

3.7 PROJECTIONS FOR THE FUTURE

3.7.1 The Relevant Time Horizons

What is the time horizon of today's tightness in the IT labor market? It is useful to distinguish between long-term trends (measured in decades) and more cyclic phenomena likely to occur in the shorter term.

Over the long term, continued growth in the IT sector and in the use of IT by IT-intensive firms is highly likely. But growth in any sector is rarely monotonic. All sectors--as well as the economy at large--experience periods of greater and lesser growth (or even contraction). When they occur, downturns in the IT sector and in the IT-intensive industries may:

Reduce the amount of IT work that users are able to pay for,

Increase the number of workers available to (or trainable for) IT work, and/or

Reduce the value capital available (e.g., stock options) for compensation of IT workers.

The timing of these periods of growth and contraction is difficult to predict. Until contraction occurs, the current tightness being experienced by the IT sector and by many IT-intensive firms is likely to continue. But a downturn in the overall economy (e.g., as a result of inflation, significantly higher interest rates, or a stock market collapse) would have some effect by dampening demand to some extent for IT products and services, as well as a downward influence on wages.27 On the other hand, there is some historical precedent for thinking that the IT sector might be affected less severely than other sectors by an overall downturn and even that IT growth can continue during an overall downturn. Such an outcome was observed in the early 1990s, which saw an overall slowdown in the economy but continued capital spending on IT. An additional effect of

an overall downturn would be a slackening in the overall labor market, a phenomenon that might make IT a more attractive employment choice for people not now in the IT sector or in IT-intensive firms and thus increase the potential supply of new IT workers.

Even absent a downturn, current growth rates in market capitalization, revenues (for those that have them), and numbers of job openings in some segments of the IT sector and in IT-intensive firms may well be unsustainable. For example, as firms complete their transitions to the Internet and e-commerce (likely on a time scale of years and perhaps decades), the personnel needed may move from those needed for transition (a larger workforce) to those needed for maintenance and sustainment (a smaller workforce).

Whatever the cause, a downturn in the IT sector (and to a lesser extent, in the IT-intensive industries) would most likely result in reduced demand for IT workers. As importantly, because the labor market takes time to adjust, periods of downturn are likely to result in slackness (as compared to today's tightness) in the IT labor market. For example, students who have been attracted to study IT in colleges and universities by a tight labor market may face a slack labor market by the time they graduate--and end up taking jobs in fields other than IT.

3.7.2 The Quantitative Outlook

The IT sector of the economy is strong and growing, as is true for many IT-intensive firms, and high demand for the Category 1 IT professions, as well as for support positions, is likely to continue. Bearing in mind that rapid changes in levels of tightness across occupations can be driven by currently unforeseen technological, business, or economic developments, the IT labor market is likely to remain strong for a long time to come. BLS projects that the fastest-growing occupations between 1998 and 2008 will be the group consisting of computer systems analysts, engineers, and scientists, projected to grow from 1,530,000 jobs in 1998 to 3,052,000 jobs in 2008, an increase of 99.4 percent (an average of 164,000 jobs per year, or 6.9 percent per year).28 Jobs in computer programming are projected to grow by 29.5 percent, from 648,000 to 839,000. The projected growth across all occupations, both IT and non-IT, is 14.4 percent, or 1.3 percent per year.29

Within the group, jobs for computer engineers and scientists will increase by 103.4 percent, and those for systems analysts by 93.6 percent. Computer engineers and scientists are further broken down into computer engineers (107.9 percent increase), computer support specialists (102.3 percent increase), database administrators (77.2 percent increase), and all other computer scientists (117.5 percent increase).30 Overall, the top five fastest-growing occupations between 1998 and 2008 are expected to be computer engineers, computer support specialists, systems analysts, database administrators, and desktop publishing specialists.

In recent years, BLS projections have consistently underestimated the number of IT jobs that the economy will create. In particular, it is possible to compare the BLS projections of computer programmers, systems analysts, and computer scientists and engineers made in 1996 for 1998 with the actual reported numbers for 1998.31 An analysis of these 1996 BLS projections indicates that they were about 93 percent of the actual 1998 figures. Furthermore, the annual growth rate in these occupations (taken in aggregate) implied by the 1996 projection was 5.0 percent, whereas the growth in actual employment from 1996 to 1998 reflected a 9.6 percent annual growth rate.

What is responsible for such underestimation? While the BLS does provide comprehensive public-domain occupational forecasts, these forecasts are based on procedures that are subject to significant methodological criticism. For example, the procedures assume a fixed relationship in each industry between the number of jobs and total person-hours. This is clearly problematic, since very strong evidence exists that this relationship changes over time and will continue to change as the fixed costs of employment rise relative to variable costs and as the relative importance of overtime cost declines. Moreover, the assumption of such a fixed relationship amounts to an assertion of the interchangeability of persons and time worked, an assumption that is not valid in many sectors (including much of IT) in which team efforts are central. Finally, the BLS methodology neglects many dimensions in which adjustment may occur, including training and retraining, and especially response to changes in wages. None of the past changes in

the relationships are assumed to have been affected by anything behavioral--everything is summarized in the time trend. For these reasons, it is likely that the underestimation of the growth in IT job categories will continue.32

The state of the labor market, of course, depends on more than demand--supply (by which is meant all sources of labor that could do useful IT work) matters as well. Elements of supply include individuals entering the IT workforce for the first time, individuals in the IT workforce who are inclined to leave the workforce unless given incentives to stay, individuals in the IT workforce who shift from areas of low demand to areas of high demand, individuals in other lines of work (or currently unemployed) who could move into the IT workforce, individuals currently working in a low-demand IT segment who could move into high-demand IT segments (perhaps with some retraining), and foreign IT workers who might be employed (either in the United States or abroad) to perform IT work on behalf of U.S. companies. Approaches to increasing supply are the focus of Chapter 7.

3.7.3 Skills for the Future

Because it is--by definition--impossible to predict discontinuous changes in technology, assessments of the specific skill sets needed in the future can be based only on what is known today. With that caveat, it is likely that the types of IT worker in greatest demand over the long run will fall into three categories:

Those who combine strong knowledge of a specific business with IT skills. As IT applications to support effective decision making become ever more pervasive throughout business, industry, and government, organizations in these sectors are likely to realize the benefits of process reengineering. Effective reengineering of business processes requires good knowledge of what a firm is trying to do as well as good instincts for what IT can and cannot do. IT is becoming central to many fields, such as finance and health care, and thus a dual competency will be increasingly useful.

Those with the skills to work with recent information technologies that have broad-ranging business application. Because information technologies change rapidly, those with the most recently acquired skills useful for technologies with broad application (or the ability to learn these skills quickly) are likely to be in very high demand. These individuals will be able to fit into a wide variety of organizational venues and businesses. And, because future applications will probably be more complex compared to the applications of today, those with the ability to manage complexity very well are especially likely to be in high demand.

Those with extraordinary mastery of hard-core technology skills. There are always firms that need to squeeze the last bits of performance and functionality out of the information technologies that they use. While the number of such firms that are willing to pay large premiums for such efficiency is small (mostly because such efficiency is not necessary for most IT-sector or IT-intensive businesses), individuals with extraordinary mastery ("wizards") will be in high demand for those that are so willing.

3.7.4 Project-based Employment

For much of the latter half of the 20th century, many jobs were characterized by relatively high stability--long-term employment with one firm. Typically, these relationships involved assistance to employees for maintaining and upgrading skills to accommodate changing work assignments (because the firm perceives a stake in those skills) and salary structures that compensate junior or newer workers less than senior or older workers, in effect implementing a discount for lower productivity during the time new skills are being acquired early in a career. Of course, in practice, many workers did change employers, but such changes tended to be infrequent and measured in many years or decades.

In another mode of employment that this report calls project-based, the firm uses a worker (and compensates him/her, either directly or indirectly) for a specific task, without obligation to continue employment beyond that task. (For ease of discussion, it is helpful to distinguish between the firm that

needs work to be done and the employer that actually employs the worker. These may or may not be identical.) Project-based employment can take several forms:

A "regular" employee of the firm, receiving benefits (e.g., health insurance), pension, or stock options or equity stakes, but without the expectation that he or she will necessarily remain with the company after his or her stock options vest. Such an individual may well move from project to project within the firm, but must "job-hunt" within the firm once a given project has ended.

An individual independent contractor ("self-employed") with very well defined (and usually time-delimited) responsibilities to the firm, which has no responsibility to the contractor other than paying the agreed-upon fee.

An employee of a third party such as a personnel firm, a temporary help service, or a consulting or contracting firm. In such instances, the firm contracts with the employer for either an individual to work on projects of the IT firm's choosing or a product or service that the employer will deliver to or on behalf of the IT firm. This practice, often referred to as outsourcing, started to become more common more than 10 to 15 years ago.

In all of these instances, compensation for the worker is geared to the current worth of the worker to his or her employer for the duration of the task. The firm has no responsibility to the worker to ensure that his or her skills remain current or that he or she remains useful for another task for the same firm--skills are the worker's responsibility. Furthermore, in some instances, shorter job tenures are common, which may be due to the nature of the work in a sector in which workers can be displaced after a project ends.

Both firms and individual workers may have some incentives to prefer project-based arrangements.33 For example, firms may obtain greater flexibility to address economic, strategic, and technological changes with project-based workers because they can more easily change the size and composition of their effective labor forces. Because such workers are not guaranteed jobs beyond their current project, the firm has opportunities to change workforce size and composition at the end of every project. Such arrangements can be useful in managing product cycles, during which personnel requirements are much larger before product release (i.e., during development) than afterwards, or in making conversions to new technology or products generally.

In addition, the use of workers with varied job histories in the IT field enables firms to capture experience, intellectual sophistication, and knowledge that a new employee may have gained in working for a different firm (or on a variety of previous projects). While exploiting proprietary information belonging to competitors is illegal and unethical, a worker working at any given IT firm learns much that is not proprietary and that can benefit another IT firm. Moreover, the experience that a new worker can bring from a different IT firm means that the present IT firm does not have to subsidize the new worker's learning. This kind of human capital flow has been a feature of successful IT-focused regions, such as Silicon Valley.

Finally, through the use of some types of project-based employees, such as independent contractors or service firms, firms can avoid paying fringe benefits and employment taxes. Similarly, the use of contractors or service firms allows a firm to avoid many of the costs of recruitment, training, and termination incurred to comply with laws protecting regular employees. Also, the use of contractors and service firms is sometimes "off the books" from a firm-wide perspective, which enables individual managers to obtain additional labor without having to clear it through the company hierarchy.

Some workers also may find project-based employment advantageous, and their availability for such work can feed the growth of such employment.34 Project-based employment allows a worker to obtain experience at multiple firms and learn new skills more quickly by being a "regular" employee of several different firms over a period of time. Another benefit of such varied experience may be financial: individuals who wish to build their own stock portfolio of pre-IPO shares may be able to diversify their holdings in order to improve their chances that at least one of the companies for which they have worked will in fact have a successful initial public offering. More generally, independent contractors may benefit

from greater flexibility with respect to work schedules, the freedom to accept or reject assignments, or a greater range of insurance options (e.g., health plans). And, many "free agents" do well as high-end consultants or well-paid workers with skills in critical areas, because it is difficult for companies to find permanent employees with these abilities. At the same time, free agents with skills in less critical areas tend to make less than their permanently employed counterparts. Thus, the economic consequences of project-based employment are far from uniform. Finally, free agents must cope with occasional job instability and often receive fewer benefits than permanent workers.35

Because both workers and firms may perceive benefits to these more flexible arrangements, project-based employment appears to be increasingly common, and Web-based businesses have begun to emerge to provide matchmaking between parties offering and seeking work.

3.7.5 Reducing Relative Needs for Personnel Through Tools and Techniques for Greater Productivity

Historically, the personnel needs of many fields, e.g., agriculture and manufacturing, have been reduced by the use of machinery to displace labor. Indeed, many economic models of productivity36 are built around the assumption that, to varying degrees, capital can substitute for labor. Different management approaches have also helped to improve productivity in certain instances. It is thus reasonable to ask if such approaches might be promising in the field of IT.

Tools

For IT, the analog of mechanized agriculture is tools that enhance individual productivity, noting that productivity is, by definition, the ratio of useful output to human work input to produce that output. In agriculture, for example, the use of tractors, threshers, and the like enables the production of far larger amounts of food for a given number of farming hours than would be possible with the use of oxen-drawn plows and scythes. In information technology, widely used operating systems, language compilers, debugging tools, performance analysis systems, environments for program maintenance and integrated development, component frameworks, rapid prototyping tools, and problem-solving systems have all helped to increase the productivity of Category 1 workers.

The development of more and better tools to enhance individual programmer productivity remains an active area of research and development. It is likely that such tools (as illustrated in Box 3.6) will indeed emerge as the result of continued research and development in the area, although the magnitude of the productivity improvements that can be expected from the use of tools is a matter of sharp dispute within the IT community.

Management and Organization

Management strategies and organizational approaches may result in higher productivity. Software development does not have a consistently good track record for quality, and from the earliest days of programming, there have been concerns about cost and time overruns and program reliability. As systems became larger, the opportunity for error became greater. Indeed, because the development of large systems requires teams, and all teams are organized in some manner, the role of organization and management is manifest.

Over the past few years, the Standish Group has surveyed a wide range of organizations on the outcome of their IT projects.37 Overall the results are poor. In 1994, 31 percent of projects were canceled before completion, and a further 53 percent were completed over budget. Two years later, the corresponding results were that 40 percent of projects were canceled before completion and 33 percent were completed over budget, and in 1998, the results were that 28 percent of projects were canceled before completion and

46 percent were completed over budget. Although these results do show some improvement over time, the results for 1998 are still very unsatisfactory. Common sources of project cancellations and overruns include ill-defined or changing requirements, poor project planning or management, uncontrolled quality problems, unrealistic expectations or inaccurate estimates, and naive adoption of new technology.38

In addition, individual projects can be organized in ways that minimize personnel needs over the life cycle of a product. For example, software inspection for quality at the front end of the development process has been shown to reduce dramatically the amount of rework and debugging that otherwise needs to be done at the end of the process.39 Thus, even though initial costs are higher, overall personnel needs can be lower.40

Finally, firms that use IT workers may outsource non-core competencies that involve IT to specialized service firms, thus reducing the need for in-house IT staff. Today, many non-IT companies, such as financial institutions, are reducing their need for whole categories of IT personnel because they cannot compete internally with what they can buy relatively cheaply on the outside; as a result, they have less need to build IT systems in house. With outsourcing, the same amount of work needs to be done through the economy as a whole, but a specialized service firm may well be able to undertake work more efficiently because of efficiencies of scale or greater experience and knowledge in providing the service.

Arguments about the importance of management practices in the development of IT software have been made for at least three decades. There is disagreement in the IT community about how much more can be gained by better management practices. Some believe that much can be gained if every project used the best management practices, for example. (See Box 3.7 for a discussion of illustrations.) Others feel, however, that while there is undoubtedly some productivity to be gained, there is no silver bullet in such an approach, largely because software development is an extremely complex process.41

The Likely Impact of Improvements in Productivity

For a fixed amount of work, the impact of productivity improvements, whether from tools or management techniques, is to reduce the number of personnel needed to perform that work. If the work that needs to be done (otherwise known as demand for labor) increases, then the impact of productivity improvements is to reduce the number of personnel needed below the number that would be needed in the absence of such improvements. Furthermore, to the extent that productivity improvements make it easier for people with less expertise and training to accomplish what previously took greater skill, such improvements may well serve as one stimulant of additional demand for IT labor.

Historical experience, compiled by Boehm,42 suggests that the use of improved tools and improved management has resulted in an annual growth rate in software productivity of about 7 percent for the past 30 years. If this trend can be extrapolated to the future, it will approximately compensate for the 8 percent annual increase over all of the "core" IT occupations over the next 10 years projected above. If this is true, the impact of productivity improvements will be to maintain the approximate status quo with respect to the current tightness in the IT labor market.

However, as noted above, recent comparisons of actual to projected demand indicate that U.S. government projections have underestimated the rate of job growth by almost a factor of 2. And, the rate of job growth in certain specialties is likely to be even higher. Boehm estimates that annual improvements in productivity of 10 percent are possible if new techniques are used more widely, though his analysis is qualified by both the fact that it uses equivalent machine language instructions as the output measure (a controversial measure in the IT community) and the fact that it is based on large software systems usually built on contract for the federal government (a point that may limit its applicability to many important software development efforts in the private sector).

These comments indicate that while productivity tools and techniques have a role to play in reducing personnel requirements below what they would otherwise be, they are not likely to play a decisive role in reducing the current tightness in the IT labor market.

3.8 RECAP

A primary manifestation of a tight labor market is the fact that many--perhaps most--employers of IT workers report large numbers of vacancies for IT positions. However, turnover and company growth contribute equally to the vacancy rate. Overall, today's IT labor market is tight, although the nature and extent of such tightness vary by employer, by type of IT work involved, and by geographical locale. The fundamental driver of this tightness is growth in the use of IT throughout a strong economy, a tightness that is significantly exacerbated by the currently low unemployment rate in the overall labor market.

The behavior of wages, a common indicator of labor shortages, presents a mixed picture. Base wages for Category 1 workers (apart from those in hardware, about which little is known) have been rising at a rate of about 4 percent per year in constant dollars. However, this overall behavior masks much more rapid wage growth in certain subspecialties and less rapid growth in others. Furthermore, the presence of unexercised and/or unvested stock options and equity stakes in the compensation of workers in a relatively new and growing industry may help to explain the fact that mean wages in the IT sector have risen only somewhat more rapidly than wages in other sectors of the economy. Because stock options and/or equity stakes that represent deferred compensation are an increasing part of worker compensation packages in IT, as suggested above, wages alone become a poorer measure of total compensation as time goes on. Thus, the omission of stock options and equity stakes is problematic in comparing wage trends in IT versus those in other sectors.

The federal IT workforce presents special problems. Many government functions depend on IT, but government's ability to respond as the market would respond is limited, especially with respect to the compensation packages it can offer.

The time horizons of the current tightness in the labor market are hard to predict. In the long term (measured in decades), continued growth in the IT sector and in the use of IT by IT-intensive firms is highly likely. On the other hand, all sectors--as well as the economy at large--experience periods of greater and lesser growth (or even contraction). When they occur, downturns in the IT sector and in the IT-intensive industries may reduce the amount of IT work that they can supply, increase the number of workers who are available to do (or are trainable for) IT work, and reduce the value of capital available (e.g., stock options) for compensation of IT workers. Such downturns are also likely to result in reduced demand for IT workers, with a consequent decline in the need for foreign temporary nonimmigrant IT workers and a slack labor market.

Current projections for job growth for Category 1 IT workers, which do not take into account the possibility of such downturns, indicate strong growth for the next decade, about 7 percent per year. Historically, such projections have understated actual growth rates by as much as a factor of 2.

Analytically, there are only a few ways of dealing with tightness in a labor market--to increase the productivity of individual workers so that a smaller number of workers can do the same work that a larger number of workers can do in the absence of productivity measures, and to increase the number of qualified workers. (Reducing demand for IT products and services, and hence the need for IT workers, is a third logical possibility, but one that contradicts the premise of continued growth in the use of IT.)

Productivity can in principle be increased through the use of tools (e.g., integrated programming environments) and/or the use of different organizational or managerial strategies (e.g., structuring projects with more "up-front" design effort to reduce "downstream" personnel needs). Over the past 40 years productivity gains have been achieved through new management paradigms and technology. Similar gains are likely in the future, although they are not likely to play a decisive role in reducing the current tightness in the IT labor market.

Approaches to increasing the supply of workers and making more effective use of the existing workforce are discussed in Chapters 6 and 7.

Notes

1 Large vacancy rates are not surprising given the low levels of unemployment in the IT sector. As a rule, vacancy rates tend to move in inverse relation to the unemployment rate and positively with the employment and population rate. See, for example, Katz, Lawrence F., and Alan B. Krueger. 1999. "The High-Pressure U.S. Labor Market of the 1990s." Brookings Papers on Economic Activity, Vol. 0, No. 1). Available online at <http://www.irs.princeton.edu/pubs/working_papers.html>.

2 In some cases, vacancy counts may also reflect multiple countings of single openings. For example, consider N companies bidding on a large government contract. For planning purposes, it is prudent for each company to anticipate winning the contract--and it is a small step from that anticipation to anticipating the need to staff the project. But if all companies act in this way, and only one company can win the contract, then the number of anticipated openings is N times the number of openings that will actually be realized with the contract award.

3 As noted in Section 3.7.5, the extent to which tools, management, and organization can be used to reduce personnel needs is the subject of some controversy within the information technology community.

4 Joint Venture: Silicon Valley Network. 1999. Joint Venture's Workforce Study: An Analysis of the Workforce Gap in Silicon Valley. Palo Alto, Calif.: Joint Venture: Silicon Valley Network.

5 The Bureau of National Affairs estimates that the turnover rate for all employees in 1998 averaged 1.1 percent per month, or about 14 percent per year. See Bureau of National Affairs. 1999. Turnover Holds at Highest Levels of the 1990s, BNA Survey Finds. Washington, D.C., March 17. Available online at <http://www.bna.com/press/trn98r1.htm>.

6 As discussed at greater length in Chapter 7, employers are often concerned that they will not reap the full benefits of investments they make in training employees because employees are generally free to leave for other employment. Thus, they may be less willing to provide training than they might otherwise be.

7 Matloff, Norman, "Debunking the Myth of a Desperate Software Labor Shortage," testimony to the U.S. House Judiciary Committee Subcommittee on Immigration, April 1998.

8 Vaas, L., A. Chen, and M. Hicks. 2000. "Web Recruiting Takes Off." PC Week, January 17, pp. 57-68.

9 Murphy, Kevin, and Zinta Byrne, "Applications of Structured Assessment in the IT Workforce," commissioned paper prepared for the Committee on Workforce Needs in Information Technology, March 2000.

10 USA Today, December 10, 1999, p. A-1.

11 BLS uses the North American Industrial Classification System, which defines "computer-related business services" as companies that provide software services, data processing, and information services, and rental, maintenance, and other computer-related services.

12 One caveat is needed. To the extent that high school students take courses of study that make it more difficult to study IT-related subjects in college, such students will be unable to respond effectively to market signals indicating the desirability of the IT field. While these students may not be precluded from undergraduate study in IT-related areas, they may well have to take remedial courses after high school--and thus the entry of these students into IT work is likely to be delayed even further.

13 First-year college students will often choose majors based on what they expect demand to be for those majors when they graduate. While it is highly unlikely that college students select majors on the basis of BLS wage data, media coverage of the information technology sector has often highlighted the riches that are available to those working in it, and it is not implausible that students are influenced by such coverage. In addition, students may well choose their major based on factors such as "word of mouth" regarding compensation and other benefits. (See, for example, Freeman, Richard B., 1973, "A Cobweb Model of the Supply and Starting Salaries of Engineers," Industrial and Labor Relations Review 30(2):236-248, which documented undergraduate engineering students behaving as though they know--in relatively short order--highly precise variations in the wage data.)

14 Note that in general, demand is more elastic for firms than for an industry or the entire economy (see, for example, Eherenberg, Ronald, and Robert Smith. 1993. Modern Labor Economics: Theory and Public Policy. Fifth Edition. New York: Harper Collins). An individual firm can quickly obtain all the workers it wants by raising compensation to a sufficiently high level, because it can recruit workers from other firms who have similar positions and comparable skills and experience. Of course, other individual firms can react by matching the increased levels of compensation, so that any market advantage gained by raising compensation is transient. The industry as a whole does not have this alternative, and so it is fair to say that the labor market for a firm is generally more elastic (compensation-sensitive) than the labor market for an industry as a whole.

15 See Barnow, Burt, John Trutko, and Robert Lerman. 1998. Skills Mismatches and Worker Shortages: The Problem and Appropriate Responses. Draft Final Report. Washington, D.C.: Urban Institute. February 25.

16 Barnow et al., 1998, Skills Mismatches and Worker Shortages.

17 The significance of the incompleteness is not entirely clear. In particular, though the BLS data do not include nonwage

compensation (which affects the overall level), the impact of this omission on inferences based on trends over time is not clear. There are good reasons to believe that the omission does affect these inferences (e.g., because of rising value for stock options and equity stakes), but this effect has not been conclusively established.

18 Summary results from a private survey were provided to the committee. The data used for this study were taken from the SC/CHiPS Professional & Managerial (P&M) Total Compensation Survey for 1999, 1998, and 1997. Now in its eleventh year, SC/CHiPS is led by a steering committee of firms and is managed by a partnership between Executive Alliance, an information technology human resources consulting firm, and Buck Consultants, an international firm specializing in actuarial and benefits services. The universe of firms participating in the 1999 version of the survey included approximately 180 high-technology companies, ranging from Microsoft, Apple Computer, Intel, IBM, and Oracle to medium-size and smaller firms as well.

19 Several authors have developed models of labor market equilibrium and disequilibrium. Arrow and Capron (1959) describe a situation in which demand rises (the demand curve shifts up) but supply does not rise (the supply curve does not shift), and the wage rises at a rate that is proportional to the size of the gap between demand and supply. As the wage rises, the quantity demanded falls, and asymptotically (in infinite time) a new equilibrium is reached with a higher wage and the quantity demanded back at its original value. In contrast, the present paragraph describes a situation in which demand rises, causing wages to rise, and supply also rises in response to the rise in wages. If demand eventually levels off, then supply will eventually catch up (although maybe only asymptotically). If demand continues to rise, then supply may never catch up. In the model of Radner (2000), this happens because the supply increases at a rate that is proportional to the gap between the current wage and the wage of workers in other occupations (skill categories) with comparably long education and training. As demand continues to increase, the wage gap also increases in magnitude, and hence so does the gap between demand and supply (although the gaps may remain constant in percentage terms). On the other hand, in the model of Ryoo and Rosen (1996), supply may catch up to a continually increasing demand, because potential entrants have "rational expectations" about the labor market and exactly the right number plan ahead to enter the labor market in order to equilibrate it. (For full references to the cited articles, see the footnotes to Box 3.2.)

20 This combined requirement for management skills and deep technical knowledge seems to be more characteristic of the IT sector than in other industries, where less technical or less technology-specific background is required for management (Salzman, Hal, "Information Technology Labor Markets," commissioned paper prepared for the Committee on Workforce Needs in Information Technology, 2000).

21 Joint Venture: Silicon Valley Network. 1999. Joint Venture's Workforce Study: An Analysis of the Workforce Gap in Silicon Valley. Palo Alto, Calif.: Joint Venture: Silicon Valley Network.

22 More recently (in the last year or so), anecdotal evidence suggests that at least in some geographical areas, stock options and equity stakes provide insufficient financial incentives for certain workers in start-up companies, and so such workers command higher salaries than they might have in the more distant past, especially as compared with more well established firms.

23 These challenges are also documented in the CIO Council report of June 1999 (Hobbs, Ira, and Gloria Parker. 1999. Meeting the Federal IT Workforce Challenge, Washington, D.C.: CIO Council Education and Training Committee, June. Available online at <http://www.cio.gov/docs/Documents.htm#itwork>).

24 Thompson, Fred. 1999. "Responding to the Crisis in Information Technology Skills," report to the Secretary of the Treasury, February. Available online at <http://www.treas.gov/itwip>.

25 Thompson, 1999, "Responding to the Crisis in Information Technology Skills."

26 For the draft classification standards for federal IT positions, see Office of Personnel Management, 2000, Administrative Work in the Information Technology Group, Washington, D.C., July, available online at <http://www.opm.gov/fedclass/html/whatsnew.htm>.

27 For example, as noted in Chapter 2 (Figure 2.7), beginning salaries for bachelor's degree recipients in computer science experienced a downward trend in the early 1990s, a time that coincided with a downturn in the IT industry.

28 The BLS forecasts are based on a number of commercial macroeconomic models that predict national spending in a moderate number of major components of the gross domestic product. The spending in these categories is attributed to each of a much larger number of commodities, and the demand for these commodities is then linked to final demand in each of a large number of industries using input-output tables. Employment by each industry is then calculated by extrapolating the historical trend in the relation of industry person-hours employed to industry output. Person-hours are then converted to jobs in each industry by assuming a constant average hours per week in the industry. Employment by industry is converted to employment by occupation using a matrix showing employment in 513 detailed occupations in each of 260 detailed industries. This matrix has the characteristics of, although not the same content as, an input-output matrix. Finally, narrow demographic groups forecast labor supply as projections of the labor force based on past trends of participation. (Adapted from National Research Council, Office of Scientific and Engineering Personnel. 2000. Methods of Forecasting Demand and Supply of Doctoral Scientists and Engineers: Proceedings of a Workshop. Washington, D.C.: National Academy Press.)

29 Braddock, Douglas. 1999. "Occupational Employment Projections to 2008," Monthly Labor Review 122(11):51-77.
Available online at <http://www.bls.gov/opub/mlr/index.htm>.

30 Braddock, 1999, "Occupational Employment Projections to 2008."

31 For the source of the 1996 projections, see Silvertri, George T. 1997. "Occupational Employment Projections to 2006,"
Monthly Labor Review (11):58-83. For the source of the actual 1998 numbers, see Braddock, 1999, "Occupational
Employment Projections to 2008."

32 For more discussion of the limitations, see National Research Council, Office of Scientific and Engineering Personnel,
2000, Methods of Forecasting Demand and Supply of Doctoral Scientists and Engineers, the report from which this
discussion is derived.

33 Much of this analysis is based on Kunda, Gideon, Stephen R. Barley, and James Evans, 1999, "Why Do Contractors
Contract? The Theory and Reality of High End Contingent Labor," draft working paper, June. While the discussion in this
section addresses incentives, it is silent on the downsides of high-mobility employment, since it is intended only to explain
why high-mobility employment is increasing. The Barley paper discusses many of the downsides, as does the following
popular press article: Downey Grimsley, Kirstin. 2000. "Independent Contractors' Victory in Microsoft Case May Have Wide
Impact," Washington Post, January 16, p. H01.

34 A study conducted for the Kelly Services employment agency by EPIC/MRA, a marketing research consultancy, found
that 64 percent of IT workers either want to work as a free agent or are open to the idea. According to the Kelly study, more
than 36 percent of IT free agents earn more than $100,000 per year.

35 Edwards, John. 2000. "Redefining IT Career Paths for the New Millenium," IEEE Computer 33(1).

36 The committee notes that the term "productivity" is used in many different contexts. The basic definition of productivity,
and the one used in this report, is the ratio of output per unit input. The term is also used in the context of describing an
individual company's competitive edge (a company is productive if it can develop and sustain an edge over its competitors)
as well as in the context of a workforce on the whole that can do more (a productive workforce is a "rising tide that lifts all
boats").

37 Johnson, Jim. 1990. "Turning Chaos into Success," Softwaremag.com. December. Available online at
<www.softwaremag.com/archive/1999dec/Success.html>.

38 McConnell, Steve. 1998. Software Project Survival Guide. Redmond, Wash.: Microsoft Press, pp. 20-33.

39 See Wheeler, David A., Bill Brykczynski, and Reginald N. Meeson. 1999. "Software Peer Reviews," pp. 454-469 in Software Engineering Project Management, Richard H. Thayer, ed. Los Alamitos, Calif.: IEEE Computer Society Press.

40 For various reasons, certain development environments militate against such an approach. For example, a small start-up company seeking to bring to market a single product against severe time-to-market pressures may not have the funding to make up-front investments in architectural design and quality assurance. Such pressure simply increases the importance of management discipline (e.g., in building such investments into the original business plan). (In some cases, pressures to be first to market can lead to excessive neglect for the test and debug phases, making the end user the beta tester!) Some interesting commentary on these pressures can be found in Minasi, Mark. 1999. The Software Conspiracy. McGraw-Hill Companies. See also Computer Science and Telecommunications Board, National Research Council. 1999. Trust in Cyberspace. Washington, D.C.: National Academy Press.

41 See, for example, Brooks, Frederick P., Jr. 1995. "No Silver Bullet," in The Mythical Man-Month, Anniversary Edition, Reading, Mass.: Addison-Wesley.

42 Boehm, Barry W. 1999. "Managing Software Productivity and Reuse," IEEE Computer 32(9):111-113.