UPSTAIRS, DOWNSTAIRS: COMPUTERS AND SKILLS ON TWO FLOORS OF A LARGE BANK

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Many studies document a positive correlation between workplace computerization and employment of skilled labor in production. Why does this correlation arise? The authors posit that improvements in computer-based technology create incentives to substitute machinery for people in performing tasks that can be fully described by procedural or "rules-based" logic and hence performed by a computer. This process typically leaves many tasks unaltered, and management plays a key role—at least in the short run—in determining how these tasks are organized into jobs, with significant implications for skill demands. This conceptual framework proves useful in interpreting how jobs were affected by the introduction of digital check imaging in two departments of a large bank. In one department, the tasks *not* computerized were subdivided into narrow jobs; in the other department, management combined multiple linked tasks to create jobs of greater complexity. The framework may be applicable to many organizations.

Two recent trends have rekindled interest in the questions of how technological change affects the skills that workers use at their jobs and the way in which these skills are remunerated. The first is the increase in earnings inequality. Since 1980, the earnings of highly educated workers have increased relative to those of less educated workers, a phenomenon that economists attribute primarily to changes in relative demands for the skills supplied by these groups of workers. The second trend is the remarkable proliferation of computers and information technology, beginning with the spread of mainframe applications during the 1970s, moving to greater use of personal computers in the 1980s, and to enormous growth in applications of networked computers in the 1990s.

A number of studies have documented positive correlations between the use of computers and the use of more educated labor in production across detailed industries and across plants within industries in the United States. Similar relationships are present in data from other industrialized countries. Some analysts cite these correlations as evidence that computers embody skill-biased technical change, meaning that computers substitute for less educated workers in performing some tasks and comple-

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ment more educated workers in performing other tasks.

Other observers reject this conclusion as unduly deterministic. Based on analyses of case studies, they argue that equating computers with skill-biased technical change ignores management's role in job and organizational design and relies on simplistic definitions of skill. In this paper, we argue that the introduction of computer-based technology creates strong economic pressure to substitute machinery for people in carrying out tasks that can be fully described in terms of procedural or "rules-based" logic and hence performed by a computer. This process typically leaves many tasks to be performed by humans, and management decisions play a key role—at least in the short run—in determining how these tasks are organized into jobs, with potentially significant implications for skill demands. We show how this model helps to interpret the consequences of the introduction of digital check imaging in two back office departments of a large bank, one of them (downstairs) processing deposits, the other (upstairs) handling exceptions (for example, overdrafts or stop check requests).

We begin with a brief discussion of the literature that bears on our case. We then turn to a discussion of what computers actually do—the execution of procedural or "rules-based" logic. This provides the background for describing and interpreting the evidence from our case study. Though we present only one case, we believe that the model—computers displacing humans in some tasks, with management decisions reshaping others—offers a potentially valuable framework for future studies of computerization's skill effects.

Previous Research

The explanation favored by many economists for the positive relationship between computer use and the demand for educated labor is *computer-skill complementarity* or skill-biased technological change.[1] The essence of this hypothesis is that technological change involving computers increases the productivity of highly educated workers more than it increases the productivity of less-educated workers. An alternative explanation popularized in books such as *The End of Work* (Rifkin 1995) is *computer-labor substitution:* computers substitute for low-skilled labor in carrying out a variety of tasks. Both of these explanations imply an increase in relative demand for highly skilled workers.

Some social scientists, particularly noneconomists, find the concept of skill-biased technological change troubling. For example, in a thought-provoking article, Paul Attewell (1990) pointed out that there are many conflicting ways to conceptualize skill. In one tradition (positivism), skill is treated as an attribute of jobs, and jobs that are substantively complex are viewed as skilled. A difficulty here is the arbitrariness of ranking along a single dimension of complexity jobs that are very different—for example, conducting biological research versus managing a large organization. Perhaps the only thing these two skilled jobs have in common is their demand for a great deal of conscious thought.

A different research tradition, ethnomethodology, sees a variety of everyday activities—walking across a crowded room or carrying on a conversation with many voices in the background—as highly skilled tasks, even though humans master these tasks with little conscious thought. The ethnomethodologists' insight is validated by decades of research in artificial intelligence (Pinker 1997); computer scientists have been relatively unsuccessful to date at programming computers to perform many of these "simple" activities, a point we return to below. These different conceptions of skill raise questions about exactly what economists mean when they refer to "skill-biased technological change" and what the predictions are about the types of tasks that

[1]See, for example, Autor, Katz, and Krueger (1998), Berman, Bound, and Griliches (1994), Berman, Bound, and Machin (1998), Bresnahan, Brynjolfsson, and Hitt (forthcoming 2002), Machin and Van Reenen (1998), and Wolff (1996).

are the most likely candidates to be carried out by computer-driven machinery instead of by people.

A different challenge to the skill-biased technological change idea comes from researchers who point out that managers often have considerable discretion in deciding how to implement new technologies, with differing implications for the organization of work and skill demands (Hunter 1999; Zuboff 1988). This observation raises the question of what factors influence managers' decisions about the organization of work. Lindbeck and Snower (2000) proposed a model in which managers create single-task jobs to take advantage of specialization when tasks are not complementary (for example, Adam Smith's pin factory), and combine tasks into broader jobs when tasks are complementary. Autor, Levy, and Murnane (2001) pointed out that workplace computerization often provides workers with vastly richer informational inputs (a process that Zuboff [1988] called "informating"), which may increase the productivity of—and demand for—analytically skilled workers who can use this information effectively.[2] Osterman (1994) argued that "high performance job designs" in which employees are involved in problem-solving, have responsibility for more than one task, and are paid for taking initiative are likely to be present in organizations in which quality of service is important and in organizations with a management philosophy that attaches importance to increasing the well-being of employees. Other scholars point to considerations of power and culture (Zuboff 1988); still others see government regulations as playing a role in some industries (Hunter 1999).

While agreeing that many factors may influence the technologies and forms of work organization adopted by firms in an industry at any point in time, many economists argue that in the long run competitive pressures will lead to the dominance of the most efficient combination of technology and work organization, if there is indeed a single most efficient combination. Of course, the longer the "long run," the less interesting the long-run outcomes are relative to the potential diversity of medium-run forms of organization and technologies.[3]

Contributions

One contribution of this paper is to provide an explicit description of the type of tasks computers can do. This is valuable in predicting the tasks in a particular organization that are likely to be automated as a result of the introduction of computer-based technology. As such, it helps to unpack the notion of "skill-biased technological change." A second contribution is to reconcile the concept of skill-biased technological change with the idea that managers typically have considerable discretion in re-organizing work when new technology is introduced. We do this in the context of a case study from the banking industry, which historically has employed large numbers of workers with no post-secondary education—the group whose earnings have fared poorly over the past 20 years (Katz and Autor 1999).

Our case study has several strengths:

—We were able to collect detailed information on the new technology that the bank introduced and the associated work re-organizations in the two departments. This helps in avoiding the error of inappropriately attributing to technological change effects on workers that stem at least in part from unobserved changes in the organization of work (Brynjolfsson and Hitt 2000).

—Through interviews with long-time workers in the two departments, we were able to verify that technology and the orga-

[2]For example, comprehensive bibliographic searches increase the quality of legal research; timely market information improves the efficiency of managerial decision-making; richer customer demographics increase the productivity of salespersons.

[3]See Adler (1992) for a thoughtful discussion of this issue.

nization of work had been remarkably stable for decades before the advent of the changes we studied.

—We were able to collect some information on changes in labor productivity and wages, data that are lacking in many case studies.

—Interviews with managers and articles in the trade literature on check processing illuminated the critical role government regulations play in constraining production processes in one of the two departments, a force that is not typically visible in large-scale statistical analyses.

Methods

It was for the reasons described above that we requested permission to study the changes in the operations of two back office departments of "Cabot Bank." We began the project in April 1998 with a two-hour interview of the vice-president responsible for the two departments and his two senior managers. Over the next 15 months, we conducted 25 semi-structured interviews with hourly workers, first-line supervisors, and managers in the two departments. Interviewees included six people who had worked in one of the two departments for more than 20 years, and six relatively new hires. The length of the interviews ranged from 30 minutes to two hours. Our questions concerned the work to be accomplished, work organization before and after the introduction of image processing, difficulties in implementing the new technology and the new work organizations, amounts and kinds of training, and wages. We also interviewed key staff people in charge of training, human resources, and accounting for the two departments. We searched for ambiguities and apparent inconsistencies among respondents in the answers to our questions and clarified these issues through follow-up phone calls and interviews.

We observed work for approximately 10 hours in each of the two departments. Our primary goal was to understand the nature of the production processes in the two departments, the organization of work, the extent and nature of interactions among workers, and the degree to which workers provided service over the phone to the bank's internal and external customers. We asked many clarifying questions of the workers we observed.

The senior managers of the two departments provided us with records of their labor productivity estimates from years antedating the introduction of the image technology to several years after the technological change and the re-organization of work. They also provided us with information on the distribution of wages in the two departments at several points over this same time period. While we had no independent source of information on productivity and wages against which to compare the figures provided by bank management, we did find that the wage figures were consistent with workers' reports of current wages and long-time employees' memories of prior wages. We were also able to use descriptions in trade journals of production processes for check processing and exceptions processing to verify and supplement long-time employees' memories.

While there is always more to understand, we believe that our methods of collecting data (interviews, observations, historical bank records, and trade literature) produced an accurate picture of the impact of the introduction of image processing and the re-organization of work on skill demands in the two departments.

What Computers Do: A Task Framework

We conceptualize work as performing a set of tasks—recording the value of a check in a ledger, resolving a processing error, mediating a customer grievance—and ask which tasks can be performed by a computer.[4] An approximate answer to this question is that computers can perform tasks

[4]Thanks go to Randy Davis of MIT's Artificial Intelligence Lab and Pete Szolovits of MIT's Laboratory for Computer Science for helpful conversations.

than can be fully described as a series of logical programming commands ("If-Then-Do") that designates what actions the machine will perform and in what sequence at each contingency.[5]

As the price of computing power has declined, the range of tasks that computers can economically accomplish has grown considerably. It is important to recognize, however, that humans accomplish many tasks quite readily that will not be computerized quickly. The reason is summarized succinctly by Michael Polanyi's (1966) observation, "We do not know how to do many of the things we do." This explains the ethnologists' observation that many commonplace manual tasks, such as mopping a floor or maneuvering a vehicle through traffic, have proven surprisingly difficult to automate. Completion of these tasks appears to require optical recognition and adaptive fine motor control that at present are poorly understood and consequently cannot (yet) be described by a computer program (Pinker 1997). Similar limits apply to programming many forms of human interaction, such as mediating disputes and gaining the trust of customers.

A different kind of limit on the tasks computers perform arises because computer programs expressed in if-then-do logic can typically only address "known" problems; contingencies unanticipated by the programmer will typically result in a dead-end.[6] For this reason, computers cannot at present readily carry out many of the cognitive and analytic tasks that managers and professionals routinely tackle, including identifying and solving ill-posed problems, and responding appropriately to unanticipated contingencies. Computers may, however, increase the productivity of skilled workers in accomplishing these tasks by speeding search and retrieval of many kinds of information. Through these mechanisms, computers appear to complement skilled workers in these tasks.[7]

This view of what computers do helps in unpacking the concept of skill-biased technological change. What computers primarily do is carry out tasks that can be described in terms of rules-based logic. Since this includes a great many back office tasks such as filing and bookkeeping, it is consistent with the empirical evidence that adoption of computer-based technologies is associated with a decline in the percentage of high school graduates in an organization's work force. Notice that tasks that will not be computerized in the near future include not only non-routine problem-solving—the type of work associated with college-educated labor—but also non-routine manual work such as cleaning buildings and removing staples from checks, tasks typically done by workers with little formal education. Finally, this view of what computers do makes no strong predictions about how tasks that are *not* computerized will be organized into jobs, leaving considerable discretion for managerial decisions, at least in the short run.

This brief sketch of the areas in which computers are likely to substitute for, as well as complement, human effort provides a framework for considering how work is reorganized when a technological change is introduced into check processing.

Check Processing

The steps that banks complete to process customers' deposits have not changed markedly since checks were introduced in the United States shortly after the Civil War. A bank must record ("capture") the amounts of individual checks, "proof the deposit"—that is, verify that the sum of the values of

[5]This proceduralization, often called rules-based logic, holds strictly at the level of programming language and describes most, but not all, commercial computer applications. Exceptions to this generalization include, for example, the self-organizing neural networks sometimes used for data mining.

[6]That is, the problem remains unsolved but the diagnostic rules offer no more alternatives. For examples of such diagnostic dead-ends, see Orr (1996) and Beamish, Levy, and Murnane (1999).

[7]This complementarity is discussed at greater length in Autor, Levy, and Murnane (2001).

checks deposited by a customer is equal to the amount indicated on the customer's deposit slip—and then post the balance to the appropriate account. The bank then separates the checks into those written by customers of the bank ("on us") and those written on other banks (transit items). It debits the "on us" checks to the appropriate account and delivers the checks written on other banks to those banks. Banks must also have procedures to handle "exceptions." These include checks written on accounts that have been closed, checks written for amounts greater than the balances in the accounts on which they are drawn, checks that customers request stop payments on, checks written for large amounts that require signature verification, and fraudulent checks.

Fifty years ago banks did all of the sorting, balancing, posting, and the handling of exceptions by hand with the aid of mechanical adding machines. The first major wave of technological change came with Bank of America's introduction of Magnetic Ink Character Recognition (MICR) in the early 1950s. Using MICR, a bank could provide its customers with checks and deposit slips with bank and account numbers imprinted at the bottom of the check in machine-readable magnetic ink. Companies including General Electric, Remington, and IBM developed reader-sorter machines that could read the information on the MICR line and sort checks according to the banks on which they were drawn (McKenney 1995). This reading/sorting was an early example of computers substituting for human labor input in performing a task that could be accomplished by equipment following a set of procedural instructions expressed in software.

Check Processing in Cabot Bank

"Cabot Bank" is one of the 20 largest banks in the United States. It has both large retail and large commercial banking operations, with branches in several states and in many countries outside the United States. The retail part of Cabot Bank has more than doubled in size over the past decade, primarily through acquisitions of smaller banks.

At Cabot Bank as at most other U.S. banks, check processing is divided into two departments: deposit processing, which handles the checks that are not "exceptions," and exceptions processing. Cabot Bank's deposit processing department, which occupies the first floor (downstairs) of a large urban facility, processes the 2.8 million checks deposited in the bank's branches and automatic teller machines each day. Until the mid-1990s, check processing at Cabot Bank centered on the position of the proof machine operator. As an example, the Cabot Bank processing center would receive a package of several hundred checks from K-Mart. The package would include a deposit slip and an adding machine tape to show that the checks had been totaled correctly. The proof machine operator would then execute the following steps:

—Remove paper clips and staples from the checks and ensure that each faced in the same direction.

—Key in the amount of each check on the right-hand side of the MICR line.

—Add up the total of the K-Mart checks and "proof" the deposit, that is, verify that the checks total to the amount on the K-Mart deposit slip.

—If the total did not match the deposit slip, examine the adding machine tape and the encoded check amounts to find and correct errors. Possibilities include a keying error by the proof machine operator, a listing error by a K-Mart employee, or a check lost in transit.

—Send the checks to the reader-sorter machine, which then sorts them by account number.[8]

[8]In a limited number of cases, the reader-sorter could not read the MICR line because the check was damaged. These unreadable checks were carried to operators of check repair machines who keyed in the MICR information on a strip of paper, attached the strip to the bottom of the check, and returned the check to be read and sorted.

During routine processing, approximately 3% of checks are identified as requiring individual attention. They are sent to the second floor (upstairs) department, exceptions processing, of the same urban facility. Exceptions must be resolved rapidly both to satisfy Federal Reserve rules for returned checks and to provide good customer service.

Ten years ago, exceptions processing was divided into a large number of narrowly defined jobs. For example, an employee who verified signatures on checks written for amounts greater than $2,000 first found the authorized signature card in a file. She then compared the signature to the signature on the check and, if a discrepancy appeared, filed a paper form that led to further action by a worker with greater decision-making authority. A check could pass through three or four levels before reaching someone with the authority to make a final decision. Another group of workers processed stop payment orders, and still another group handled checks returned for insufficient funds. In each case, a significant portion of the day was spent shuffling paper to find the right checks in a box of newly delivered items or to move checks from one group to another. Since all work was done under deadline, it created substantial employee frustration.

Female high school graduates filled most of the jobs in exceptions processing. Turnover was 30% per year, tolerable only because the skills required were minimal and could be learned quickly. Workers who stayed in exceptions processing developed expertise in one task, but had little knowledge of the work outside their immediate area. As one manager commented, "We were in a situation where people checked their brains at the door."

As the daily volume of checks rose, the cumbersome workflow created both increasing delays and poor customer service. For example, some customers who were short of cash would buy time by writing multiple checks to creditors and then issuing multiple stop payment requests. Depending on the timing, each check might trigger an overdraft exception as well as the stop payment exception. If a check was large enough, it also would trigger a signature verification exception. Each of the three clerks involved would have only a partial picture of the problem and each would have to locate the same paper check (in a large box of checks) to complete her processing. In the end, the customer might be (incorrectly) charged with both a stop payment fee and an overdraft fee. If the customer went to a bank branch to resolve the situation, there was no single person in exceptions processing for the bank to call.

While the tasks to be accomplished in Cabot Bank's deposit processing and exceptions processing departments were different, the common characteristic was the need to handle and frequently move vast numbers of checks, pieces of paper that could only be in one place at one time and could easily be misplaced.

New Technology

Over time, a set of forces was pushing Cabot Bank and its competitors to increase check-processing efficiency. The number of checks to be processed increased dramatically.[9] Nonetheless, processing had to be done quickly. Federal Reserve Bank regulations mandated that customers have access to their deposits within a specified period of time (two days for checks drawn on local banks), but regulations also required a bank to return paper checks to the banks on which they were drawn in order to receive payment. Rapid processing was necessary to minimize the costs of float. In addition, banking deregulation had increased competitive pressure to reduce cost and respond to customer demands for new and improved services (Mayer 1997).

To help address pressures on deposit processing and exceptions processing,

[9]Recall that Cabot Bank processed about 2.8 million checks per night in its central processing facility. U.S. banks in total process about 320 million checks a night, and despite the increased use of electronic transfers, the Federal Reserve Bank projects that check volume in the United States will increase by 1 percent per year over the next 15 years.

Cabot Bank introduced "check imaging" into both departments in 1994. With imaging technology, a high-speed camera makes a digital image of the front and back of each check as it passes through the reader-sorter. Imaging eliminated the bottleneck that had existed because a check could only be in one place at one time. Check images were stored on a central computer and were accessible to bank employees in both departments working at networked personal computers.[10]

Along with the introduction of check imaging, Cabot Bank adopted Optical Character Recognition (OCR) software to scan and capture the amounts on check images as the checks passed through the reader-sorter. Deposit slips were scanned in a similar way. Computerized imaging and OCR could now accomplish two tasks that had been major bottlenecks hindering productivity improvement. The first was making information on individual checks available to employees in the two departments. The digitized check images stored on the bank's central computer did not need to be moved from one worker to another; they were accessible simultaneously to all authorized bank employees working at networked computers. The second bottleneck was reading and recording the amounts on legible checks and deposit slips, an extremely labor-intensive task when carried out by proof machine operators. Both of these tasks could be automated; indeed, doing so was the reason Cabot Bank adopted the new technology. This still left many tasks to be accomplished that did not lend themselves to automation because they could not be fully described in a sequence of if-then-do steps. Managers of the two departments were responsible for determining how these remaining tasks would be configured into jobs.

[10]Imaging was not a new technology in the 1990s; lawyers and accountants were already using it to make electronic copies of wills and estate documents. However, Cabot Bank was one of the first banks to use the technology to balance deposits, a high-volume daily activity that had to be completed under significant time pressure.

The Impact of New Technology on the Downstairs Deposit Processing Department

Cabot Bank took the advice of the image processing equipment vendor to reorganize deposit processing according to a standard job template.[11] Under the template, a check first goes to a preparation area where workers remove paper clips and staples and ensure that all checks face in the same direction. These workers then deliver the checks to a reader-sorter machine that magnetizes the ink on the MICR line of the item, reads it, sprays an endorsement and sequence number on the back of the check, microfilms the item front and back, and sorts it to a program-defined pocket based on the routing information on the check. As the checks pass through the reader-sorter, an image camera captures a digitized image of the front and back of the item. At the same time, OCR software scans machine-printed and handwritten numeric amounts in a designated location of the check. Successfully scanned information is stored along with the information on the MICR line of the check. As of 1999, the OCR software successfully "read" about 57% of imaged checks.[12]

When a digital dollar amount cannot be recognized, the image is sent first to the screen of a high-speed keyer who tries to identify the check amount by looking at the numerical image written in the small line on the right side of the check. If the high-speed keyer is not sure of the amount from its numerical rendition, he or she passes

[11]The production process in deposit processing was also quite constrained by regulations, most notably the requirement that paper checks be returned to the issuing bank.

[12]The OCR software makes both Type I and Type II errors, in some cases misreading debit amounts, and in others rejecting as "illegible" checks that were in fact correctly read. Type I errors are particularly costly, because after they are caught by bank employees or customers they require laborious downstream correction. With these facts in mind, the bank "tunes" the OCR software to minimize total check processing cost.

the check image electronically to a low-speed keyer. This operator looks at the image of the whole check and, by comparing the numerical representation to the amount written in words, determines the value and keys it in. The keyed-in check amount is added to the electronic record for that check.

Once entered into the system, multi-check deposits are compared with deposit slips automatically. When discrepancies arise, a worker whose title is "image balancer" tracks them down. Using images rather than paper checks, the image balancer performs the error detection and correction that was once one of the multiple tasks performed by the proof machine operator. But the job of image balancer, like other redesigned jobs, now consists of a specialized task.

The introduction of the image and OCR technologies has resulted in an unbundling of the proof machine operator's tasks. Computers perform one of these tasks, and the remaining tasks are divided among specialized jobs. More specialized jobs have led, in turn, to a modest increase in wage dispersion among the several narrow jobs that now constitute the core of deposit processing. This specialization and associated wage dispersion is displayed in Table 1. This table illustrates two points. First, the tasks proof machine operators carried out before the introduction of image processing have been divided into four jobs, one of which is carried out by computers and three by humans. Second, the wage associated with each depends in part on the scarcity of the relevant skills within the work force.

Removing staples and ensuring that checks all face in the same direction are tasks that most adults of average eye-hand dexterity can accomplish with no training. Consequently, the hourly pay for this job (check preparer), $9.51, is the lowest among jobs in the bank's two departments.

The job of image balancing requires somewhat scarcer skills. Like the earlier proof machine operator, the image balancer must be able to discover why some deposits do not balance. In addition, whereas the proof machine operator worked with paper, the image balancer must know how to use computers and how to do the work using electronic images instead of paper checks.

Managers in deposit processing recruited former proof machine operators to become image balances because they had already demonstrated the requisite problem-solving skills. The bank provided 36 hours of classroom training followed by two weeks of support from an experienced image balancer.[13] In the end, most proof machine operators made the transition, suggesting that modest amounts of training could impart the requisite computer skills. In 1998, the average pay of the 62 image balancers was $11 per hour, 16% higher than the pay rate for check preparers.

The department's highest wages were paid to the best keyers. While check preparers and image balancers were paid an hourly rate, keyers were paid an hourly rate plus an hourly bonus based on speed and accuracy. A keyer's speed could now be monitored by computer, a feature that simplified bonus determination. Counting the bonus, the best keyers earned $13.50 an hour, $2.00 per hour more than image balancers. This relatively high wage reflected a return to effort and to the skill of being able to recognize and record check amounts extremely rapidly and accurately.[14] As one bank official said, "There is always a demand for good keyers." In fact, "always" is too strong. Due to improvements in OCR software, a growing fraction of checks are read without human intervention. One result is that the demand for keyers at the bank per million checks processed has declined.

To understand how check imaging af-

[13]Training began with playing games on the computer to develop facility in using a mouse. Substantial time was devoted to helping make the transition from working with paper checks to working with images of checks.

[14]The bank faces a strong incentive to hire and reward workers who can key rapidly, since this reduces the number of keying workstations the bank has to purchase and maintain.

Table 1. Reorganization of Check Processing at Cabot Bank.

Tasks	*Title of Workers Who Carried out Task in 1988*	*Average Hourly Wage Rate in 1988 (1998 $)*	*Number of FTE Workers in 1988 per Million Checks*	*Title of Workers Who Carried Out Task in 1998*	*Average Hourly Wage Rate in 1998 (1998 $)*	*Number of FTE Workers in 1998 per Million Checks*
Prepare checks: remove staples and ensure checks face in same direction				Check Preparer	$9.51	16
Key in amount on checks with clear printing or handwriting	Proof Machine Operator	$10.03	67	Computer		
Decipher amounts on checks with poor handwriting and key in amount				Keyer	$10 plus incentives for speed & accuracy	15
Balance the deposit				Image Balancer	$11.00	22

fected deposit processing, it is useful to begin with a question. Given proof machine operators' large variety of tasks, why were these tasks originally bundled into a single job rather than assigned to separate workers? The tasks have a natural sequence and so lend themselves to a division of labor. Moreover, accomplishing some of the tasks (balancing) requires skills not needed in carrying out other tasks (removing staples). Although we do not have a definitive answer to this question, we suspect that an important reason for bundling tasks into a single job was to reduce transactions costs associated with moving paper checks from one employee to another.[15]

The introduction of check imaging and the OCR software had two effects on this task structure. First, it created strong incentives for management to reduce costs by computerizing the proof machine operator's rules-based task of "reading" and recording the amounts on legible checks. Second, while management had discretion in deciding how to organize the three remaining non-rules-based tasks, the reduction in the cost of moving the information on checks from one worker to another created incentives to divide the tasks into specialized jobs.[16] As we discuss below, the decision about how to organize non-rules-based tasks was much less clear-cut in the exceptions processing department.

In net, these changes were skill-biased. The introduction of image processing and OCR software led to the replacement of high school graduates by computers in the deposit processing department, thereby increasing the share of bank employees who had more formal education (primarily managers).[17]

[15]The job was designed long before any of the individuals whom we interviewed became employed by Cabot bank.

[16]The tasks could not be readily programmed in if-then-do instructions, either because they involved non-routine fine motor skills (removing paper clips) or non-routine cognitive skills (reading poorly formed handwriting, balancing deposits).

[17]The employment impact was muted, however, because acquisitions led to rapid growth during the 1990s in the number of checks processed. In 1988, 67 workers in deposit processing processed one million checks per night. In 1998, 148 workers processed 2.8 million checks per night. Consequently, the 27% increase in average labor productivity between 1994 and 1999 was accomplished without layoffs.

In the future, computer-labor substitution in deposit processing is likely to increase. Further improvements in OCR software are one reason. A second reason concerns potential changes in regulations governing paper checks. State regulations currently dictate that bank customers can demand return of their canceled paper checks at the end of each month. Currently, two-thirds of the bank's customers choose this option. Federal reserve regulations require that paper checks written on other banks and deposited by Cabot Bank customers must be returned to the original banks. Changes in regulations permitting banks to provide customers with paper images of their checks and other banks with digital images of checks would eliminate the jobs of many low-skilled workers who package checks for transit to customers and other banks.[18]

Image processing may ultimately have an impact on the geographic location of deposit processing services as well. Since image keyers work with digital images, not paper checks, there is no technological reason why image keying needs to be accomplished at the site where the checks are digitized. Competitive pressure may push much of the back office clerical work to low-wage offshore locations, with a significant loss of jobs for less educated workers in the parent plant.[19]

The Impact of New Technology on the Upstairs Exceptions Processing

A central advantage of digitized files over paper files is the ability of multiple people to simultaneously access the same information. Had image technology been introduced into exceptions processing with no other changes, it is almost certain that labor productivity would have risen as employees spent less time searching for paper and more time resolving exceptions.

The vice-president in charge of exceptions processing wanted to accomplish more, however. He believed that a broader reorganization could achieve some measure of three goals: improved productivity, better customer service, and better jobs using more skills. In his words: "fewer people doing more work in more interesting jobs."[20]

He also believed that involving current employees in the redesign would both use their knowledge and gain their commitment to the new system. Managers held focus groups of exceptions processing clerks, asking them what aspects of their jobs were irritating, and what changes would make the jobs better. The consensus was that work should no longer be divided by exception type but by customer account, so that the same representative would deal with all exceptions—stop payment requests, overdrafts, and so on—connected to the given account. In this way, for example, a clerk who saw a stop payment order would anticipate a possible (incorrect) overdraft exception as well as other stop payment and overdraft exceptions from the same account. This reorganization would not be cost-free. A representative who had processed

[18]See Minehan et al. (2000) for a description of likely changes in the regulations governing check processing in the United States.

[19]One bank, Sun Trust, which operates in the southeastern part of the country, has already moved its keying operation to a central site. On recognizing that its keying operation outside Atlanta was particularly efficient, it began transmitting the images of checks from many processing sites to the Atlanta site for keying. With similar ease, these images could be transmitted to another county. Examples such as this one underscore the difficulty in conceiving of "trade" and "technology" as distinct causes of declining demand for less educated workers.

[20]The goal of making jobs more interesting is consistent with the observation that changes in tastes accompanying increased education of the work force are a factor driving workplace redesign (Lindbeck and Snower 2000). Similarly, Osterman (1994) presented evidence that a concern with workers' welfare is one reason managers create high-performance workplaces characterized by interesting jobs.

Table 2. Reorganization of Exceptions Processing at Cabot Bank.

Tasks	*Title of Workers Who Carried out Task in 1994*	*Average Hourly Wage Rate in 1988 (1998 $)*	*Number of FTE Workers in 1994 per 65,000 Exceptions*[a]	*Title of Workers Who Carried Out Task in 1998*	*Average Hourly Wage Rate in 1998 (1998 $)*	*Number of FTE Workers in 1998 per 65,000 Exceptions*
Verify signatures on checks written for large amounts	Exceptions Processing Clerk	$10.64	98	Exceptions Processing Clerk	$13.50	470
Implement stop payment orders			98			
Handle overdrafts			424			
Move information on checks from one exceptions processing clerk to another			30	Computer		

[a]There were 650 FTE exceptions processing clerks in 1994. To allocate these clerks among specialized jobs, we rely on a Cabot Bank manager's estimate that approximately 65% of clerks processed overdrafts, 15% processed stop payment orders, 15% verified checks, and the remainder moved boxes of checks from station to station.

one type of exception for a number of years would have to learn how to process a variety of exceptions using networked personal computers. Nonetheless, management accepted the plan.

In deposit processing, the lowered transactions costs of moving information led to a greater division of labor, with the proof machine operator's job broken into several specialized jobs. As illustrated in Table 2, the introduction of check imaging led to the *opposite* result in exceptions processing: narrow jobs were combined into new, broader jobs with responsibility for handling a variety of exceptions for a block of accounts.

The introduction of image processing eliminated the paper chase that had dominated work in exceptions processing. However, it did not dictate the organization of the three non-routine tasks: handling overdrafts, processing stop payment orders, and verifying signatures. Combining exceptions processing tasks into multi-function jobs made sense to Cabot Bank managers and workers. However, some banks that have introduced check imaging have kept jobs in exceptions processing specialized by function.[21] This illustrates the importance of managerial discretion in organizing into jobs those tasks that are not readily described in terms of rules-based logic.

While the new account-based workflow was designed in anticipation of check imaging, the bank began implementation before imaging technology came on line. The immediate result—a surprise to managers—was a major improvement in productivity. Before the re-organization, 650 workers processed the 65,000 exceptions each day. By the end of 1995, after the reorganization of Exceptions Processing, but before the introduction of the image technology, this same workload was completed by 530 workers.[22]

As long as the process relied on paper, significant bottlenecks remained. Clerks were still spending considerable time shuf-

[21]A Cabot Bank manager provided this information to us.

[22]Employees engaged in an 80-hour round of initial training (40 hours in the classroom and 40 hours on the job) to learn the skills needed to handle the full range of exceptions.

fling paper checks. Answering a query from a branch bank still involved a search for the right paper check. Check imaging removed most of these obstacles. By the end of 1996, a year after the introduction of the image technology, the number of workers in exceptions processing had fallen to 470.[23] Ultimately, reorganization accounted for about two-thirds of productivity gains, with technology accounting for the other one-third.[24]

Given the productivity gains that Cabot Bank realized from reorganizing exceptions processing before the introduction of the image technology, we asked managers whether the bank had considered undertaking this reengineering during the late 1980s, when check volume was rising. The common response was that the bank was focused on absorbing newly acquired banks and did not consider the reorganization of exceptions processing. The managers also stated that other banks that do not use image processing still organize exceptions processing as a group of narrowly defined jobs. It is possible, though by no means certain, that the business case in favor of reorganization became compelling only when managers knew that the productivity gains from reorganization would be enhanced by time savings from eliminating paper shuffling that image processing made possible.

Because exceptions processing clerks now had more extensive training to handle a wider variety of tasks—skills valued by the bank's competitors—management decided it was prudent to pay higher wages. In 1993, before the reorganization of Exceptions Processing, 80% of the workers were classified as "non-exempt" (that is, their jobs did not require working independently, showing initiative, or supervising others). These non-exempt workers averaged $10.64 an hour (in 1998 dollars). As indicated in Table 2, average wages in the unit were $13.50 in 1998. Most workers were moved up a pay grade as a result of successfully completing training. In addition, management steadily increased the proportion of representatives who were "exempt," reflecting their new responsibilities. By 1998, 35% of the unit was in this category.[25]

Management also expanded the pay range within each pay grade. For example, grade 23—a grade to which many representatives were initially assigned—had a 1993 range of $17,829–$26,332 but a 1998 range of $18,900–$37,100 (all figures expressed in 1998 dollars). The greater pay range reflected employees' greater scope for judgment and initiative in the redesigned job.[26] In particular, Cabot was one of the first banks to reorganize exceptions processing using check imaging, and management believed that motivated employees could recommend additional improvements. As the vice-president said, "If you do your job, you get to keep your job—but you may not get cost-of-living wage increases. If you transform your job in a positive way, you will get a raise. If you transform your job and have a positive impact on the people around you, you will get a promotion."

The story of computerization in exceptions processing illustrates two patterns identified in quantitative studies of the consequences of computer-based technological changes. The first is the loss of jobs held by high school graduates. There was a 28% decrease in the number of workers needed

[23]The acquisition of another bank led to a subsequent increase in the number of exceptions processed by the bank and the number of employees in exceptions processing.

[24]Implementation of the *paper* account-based workflow reduced by 120 the number of workers required to process 65,000 exceptions. The subsequent adoption of imaging technology reduced the number of needed workers by an additional 60.

[25]It is possible that management increased the percentage of the work force that was exempt from hourly wage rules in order to avoid paying overtime. However, we heard no mention of this in several rather frank interviews with workers in exceptions processing.

[26]Of course, the expansion in pay grades may simply reflect the bank's response to market forces that were leading to greater wage dispersion throughout the economy during these years. There was no comparable expansion of the compensation range within each pay grade in deposit processing, however.

to process 65,000 exceptions per night. A significant part of this reduction came through reorganization undertaken in anticipation of imaging technology rather than imaging technology per se. But this process—technology acting as a stimulus to reorganizing work routines—is likely to have occurred in many other industries, and so may influence patterns in the Current Population Survey and other data sources used in aggregate wage studies. At Cabot Bank, high turnover in exceptions processing meant that work force reduction did not require layoffs; but over the period, 180 positions were eliminated, almost all of them formerly held by high school graduates.

A second pattern identified by quantitative studies is a direct positive impact of computerization on skill demands. Reorganization of work and the introduction of image technology increased the skills needed in exceptions processing. Training went a long way toward increasing the supply of skills, particularly computer skills. Managers reported, however, that a more difficult skill to teach was the ability to "see the whole picture," that is, understand the sequence of steps in processing a check and recognize the interdependencies among exceptions. Accordingly, Cabot Bank managers restructured the recruiting process. Under the revised procedures, managers asked candidates to describe problems they had encountered in previous jobs or in school and how they resolved them. The intent was to identify candidates who had a history of initiative and problem-solving. In addition, candidates were interviewed by supervisors from several groups and could only be hired if multiple supervisors vetted the hire. In the words of one manager, recruits "have to be right for the whole bank; not just for my area." Managers reported that the new recruiting process favored applicants who had completed college.[27]

Management's redesign of the exceptions processing job augmented the "skill bias" of the image processing technology. Had managers retained the narrow task structure, computerization would have eliminated the jobs of many high school workers engaged in the exceptions processing "paper chase." But the broader job design also spurred managers to recruit college graduates into the department, something they had not done before. Was the new job design inevitable? Clearly not, at least in the short run. Management had considerable discretion to use the technology to either broaden the exceptions processing job or leave the previous job design intact—with image processing improving efficiency by eliminating the paper chase. For the reasons outlined by Lindbeck and Snower (2000), we suspect that Cabot Bank's choice effectively leverages the complementarities among the exception processing tasks and will be rewarded by the market in the long run.[28] But not enough time has elapsed to judge whether the different ways of organizing work in exceptions processing reflect multiple equilibria, or whether competition will reveal that one organizational form is more efficient than others.

Conclusions

By describing how a particular technological change influenced the design of work, skill demands, and compensation in two departments of a large bank, this case study illustrates three points. First, computer-based technologies are typically introduced to automate tasks that can be described in terms of rules-based logic. At Cabot Bank, check imaging and OCR software "read" and recorded the dollar amounts on legible checks and made information on checks available to all workers.

Second, the same technological change led to quite different re-organizations of

[27]The observation that college graduates function better than non–college graduates in settings undergoing change is consistent with the work of Nelson and Phelps (1966), Schultz (1975), and Welch (1970).

[28]This view is consistent with Osterman's (2001) finding that the percentage of firms adopting high performance workplace designs grew during the 1990s.

the tasks that were *not* computerized in the two departments. The likely explanation for the creation of specialized jobs in deposit processing was that this permitted economies of specialization, once imaging reduced the cost of moving the information on checks from one worker to another. In exceptions processing, managers combined tasks into broader jobs. In Lindbeck and Snower's (2000) framework, this choice can be explained by a desire to exploit task interdependencies. It also is consistent with Osterman's (1994) observation that integrative job designs are more commonplace where management attaches importance to increasing the well-being of employees, and where customer service is a critical goal. This latter goal was central in exceptions processing but not in deposit processing.

Finally, the case illustrates that the short-run consequences of technological changes may depend critically on regulatory changes. Of course, in the long run, regulations are also likely to be influenced by technological and economic opportunities.

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