Upstairs Downstairs

How Introducing Computer Technology Changed Skills and Pay on Two Floors of Cabot Bank

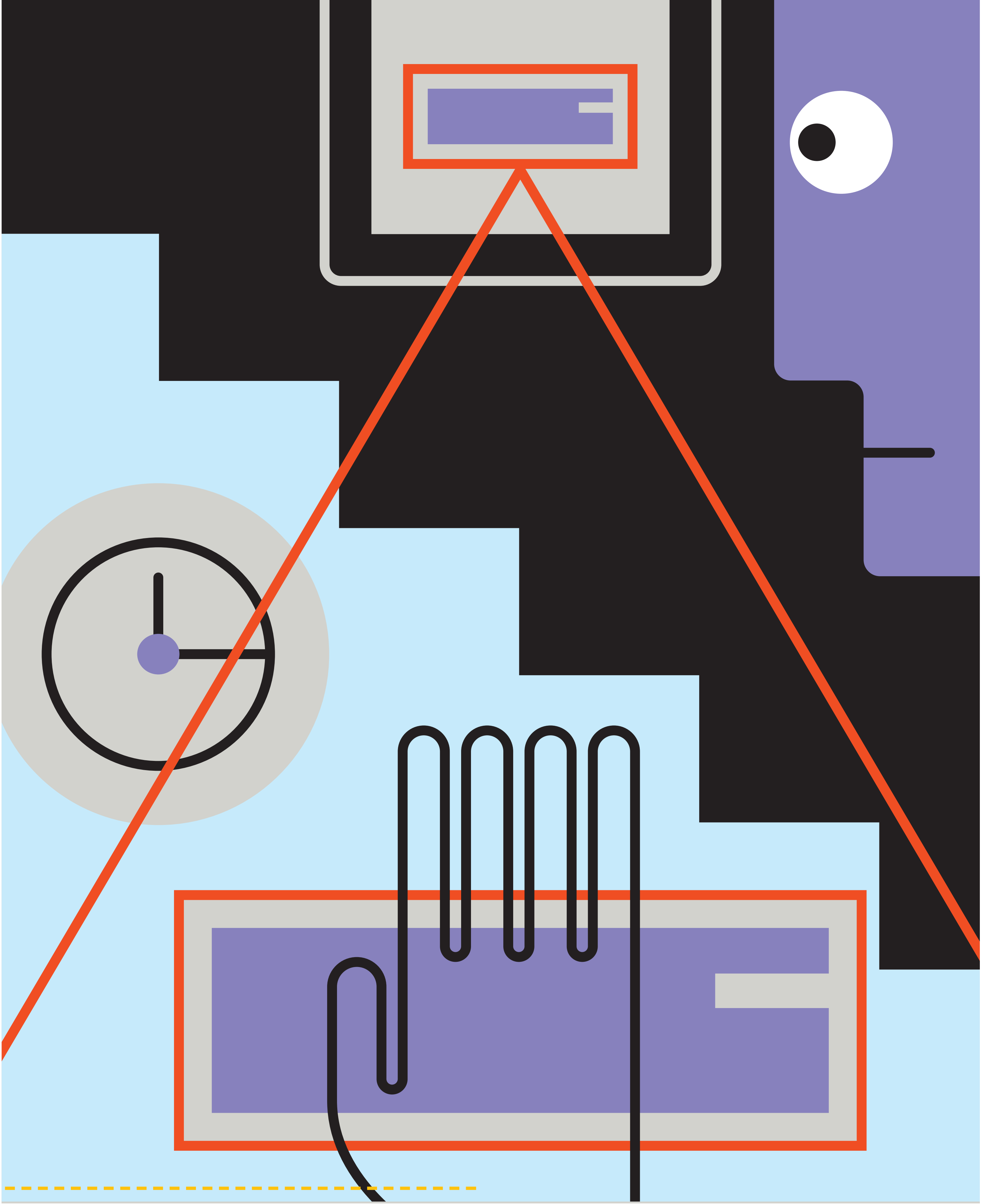
BY DAVID H. AUTOR, FRANK LEVY, AND RICHARD J. MURNANE ILLUSTRATIONS BY ANDERS WENNGREN

Cabot Bank* was one of the 20 biggest banks in the United States in 1998. It had both large retail and commercial banking operations, with branches in several states and many countries around the world. Retail business had more than doubled in size over the past decade, mostly through the acquisition of smaller banks. Every day, 2.8 million checks were deposited in its branches and automatic teller machines.

But industry consolidation and other factors were placing Cabot and its competitors under increasing pressure to improve check-processing efficiency. The number of checks passing through Cabot's doors had increased dramatically, up from 1 million in 1988. Yet, Federal Reserve regulations mandated that customers have access to deposits within two days for checks drawn on local banks and that the actual paper check be returned to the bank on which it was drawn. Speed was also important in minimizing the cost of "float" or the period of time after the deposit was credited to the customer but before Cabot collected the funds. And deregulation in the banking industry had dramatically intensified the competitive pressure to reduce costs and provide customers with new and better services.

Cabot responded by introducing two new computer technologies: check imaging (photographing checks and storing the images on computer) and optical recognition software (scanning and capturing the dollar amounts on checks and deposit slips). As one of the first U.S. banks to adopt check imaging, this immediately put Cabot in the forefront of the industry.

*not its real name



But introducing the new technologies would do more than increase productivity and reduce costs; it would also change the tasks performed by Cabot's workers and the way those tasks were organized into individual jobs—with great potential impact on employees. Would workers performing processing require greater skills and receive higher wages after the reorganization? Or would the job require fewer skills and lead to a decline in pay?

As computers have gradually become an integral part of almost every workplace, such questions have taken on a new significance—significance that goes beyond the workers in Cabot Bank or even in the banking industry. A substantial body of research finds that the rising use of computers in the modern economy is associated with an increased relative demand for educated workers, both in the United States and in other industrialized countries. Consequently, computer technology has been identified as one factor responsible for the sharp rise in wages paid to college-educated workers compared to those with less education and, therefore, an important reason for the marked increase in income inequality that has occurred over the past 25 years.

Exactly how and why does the introduction of computers result in these outcomes? Is it simply that machines substitute for less-skilled workers and reduce the demand for their labor? Or is the explanation more subtle? And perhaps just as important, is the chain of events inevitable? Or do managers have the latitude to influence the design of jobs, and consequently skill requirements and wages?

To begin to answer these questions, we followed what happened in two departments of Cabot Bank that were reorganized when the new computer imaging technology was introduced—downstairs in deposit processing and upstairs in exceptions processing. We found that computer-based technology did indeed create strong pressure to substitute machines for people in certain tasks—those that can be described by procedural or "rules-based" logic. However, this typically left many tasks to be performed by people. In those instances, we found that Cabot's management played a key role—at least in the short run—in determining how the tasks were reorganized into jobs, with important implications for skill requirements and wages.

SKILLS AND COMPUTERS

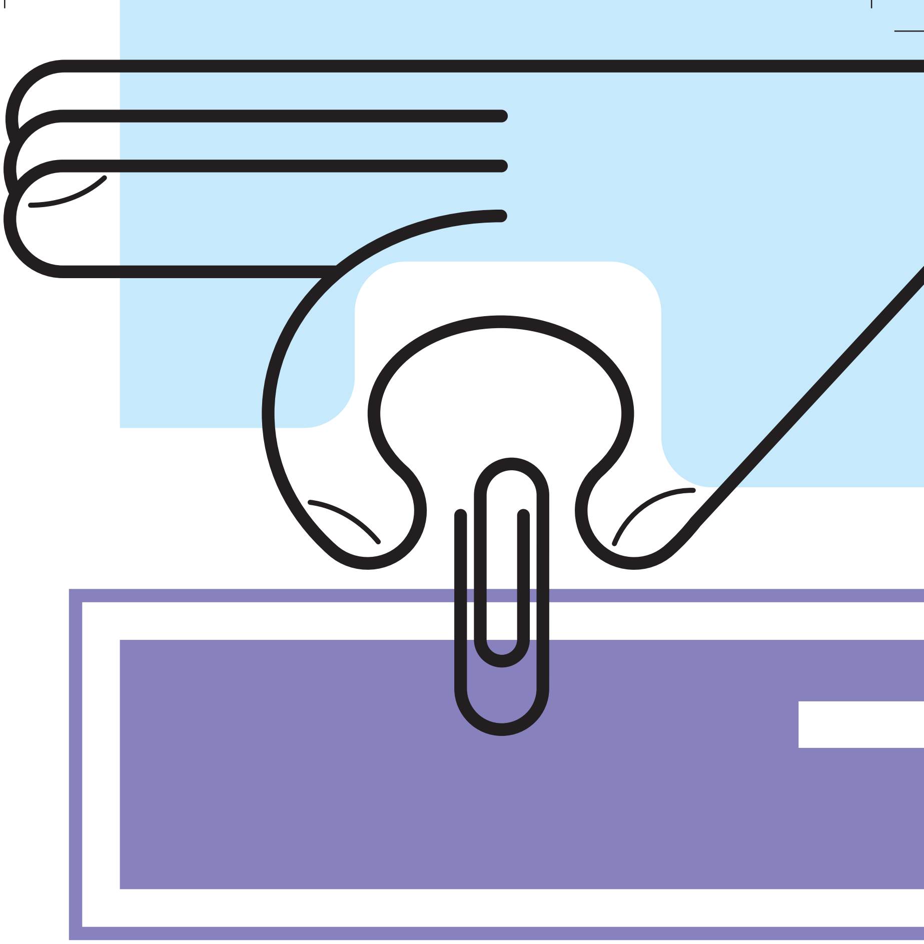
Why do we see a correlation between computers and an increased demand for high-skilled labor? The simplest argument, often seen in the popular press, is that computers substitute for low-skilled labor in carrying out tasks. In the economics literature, researchers have argued that introducing computers increases the productivity of highly educated workers more than it does the productivity of workers with less education. Both explanations imply an increase in demand for highly skilled workers relative to those with fewer skills.

But other researchers emphasize that the connection between computers and skill is more complicated. They point out, for example, that "skill" is a multifaceted concept that is not reducible to a single dimension. Which task is more skilled: conducting biological research or managing a large organization? Both are complex and difficult, each in very different ways. One thing they *do* have in common is that they require a great deal of problem solving. Yet, other activities—walking across a crowded room or carrying on a conversation with many voices in the background—are also highly skilled tasks, even though people master them with little conscious thought. As the late scientist and philosopher Michael Polanyi observed, "We do not know how to do many of the things we do."

How does this link up with what computers do? In most commercial applications, computers perform tasks that can be fully described as a series of logical programming commands ("if-then-do") that specify what actions the machine will perform and in what sequence at each contingency. (One notable exception is the self-organizing neural networks sometimes used in data mining.) Since if-then-do tasks include many relatively simple back office activities, such as recording and managing information, this is consistent with the empirical evidence that adopting computers is associated with a decline in the percentage of high school graduates in an organization's workforce.

At the same time, computer scientists have been relatively unsuccessful to date at programming computers to perform many activities that are unskilled by the definition that most humans can do them with little or no training. Commonplace manual tasks, such as mopping a floor, maneuvering a vehicle through traffic, or removing staples from checks are examples. These tasks have proven surprisingly difficult to automate because they require optical recognition and adaptive fine motor control that are still poorly understood and cannot (yet) be described by a computer program. Like walking across a crowded room, these are also among the many activities that fit Polanyi's observation. Although these tasks do not require workers with a formal education, a switch to computer-driven machinery for these jobs is not likely any time soon.

In addition, computers can typically only address known problems; contingencies unanticipated by the programmer began acquiring new banks



will result in a dead-end. So computers cannot yet carry out many of the problem-solving tasks that managers and professionals tackle routinely. However, computers may increase a skilled person's productivity in accomplishing these tasks by speeding the search and retrieval of information. For example, bibliographic searches may increase the quality and efficiency of legal research, timely market information may improve the efficiency of managerial decision making, and richer customer demographic information may increase the productivity of salespeople.

Rapid advances in computer technology—and accompanying rapid price declines—create strong pressures to computerize tasks that can be described as a sequence of if-then-do tasks. At the same time, the impact of computers on the organization of work is not deterministic. Typically, there is more than one way to organize into jobs the tasks that are not computerized. In these cases, managerial decisions can play a significant role, at least in the short run, in determining the organization of work and hence the skill requirements of jobs.

CHECK PROCESSING AT CABOT

Fifty years ago, banks did all the sorting, balancing, posting, and handling of deposits and 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 give customers checks and deposit slips with bank and account numbers imprinted in machine-readable magnetic ink. Companies including General Electric, Remington, and IBM developed reader-sorter machines that could read the information and sort checks according to the banks on which they were drawn. This reading/sorting was an early example of computers substituting for human labor.

Until the mid 1990s, the Deposit Processing Department at Cabot centered on the job of the proof machine operator. The Cabot processing center would receive a package of several hundred checks from a customer, the local supermarket for example, including a deposit slip and adding machine tape. The proof machine operator would remove the paper clips and staples from the checks, make sure that each check faced in the same direction, key in check amounts, and, finally, add the checks and verify that the sum matched the total on the deposit slip. If the totals did not match, she would examine the adding machine tape and the encoded check amounts to find and correct errors such as a keying error by the proof machine operator, a listing error by the supermarket employee, or a check lost in transit. Then, the checks were sent to a machine to be sorted them by account number.

Checks requiring individual attention were sent upstairs to the Exceptions Processing Department. These included checks written on closed accounts, checks for amounts greater than the account balances, checks with stop payments on them, checks written for amounts large enough to require signature verification, and fraudulent checks. About 3 percent of checks fell into one of these categories. In contrast to deposit processing, exceptions processing was organized into a number of narrowly defined jobs. For example, if the employee who verified signatures on large checks found a discrepancy, that person filed a paper form that led to further action by another worker with greater decision-making authority. A check could pass through three or four levels before reaching someone empowered to make a 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 boxes of newly delivered items, or to move checks from one group to another. Since all work was done under deadline, this created substantial employee frustration.

As in deposit processing, female high-school graduates held most of the jobs in the exceptions department. Turnover was high—30 percent a year—tolerable only because the skills required were minimal and could be learned quickly. Long-term employees developed expertise in one task, but had little knowledge of the work outside their immediate area. As one manager commented, "People checked their brains at the door."

As Cabot began acquiring new banks and the daily volume of checks rose sharply, the cumbersome workflow created even greater delays and poor service. For example, customers who were short of cash would sometimes buy time by writing multiple checks and then issuing multiple stop-payment requests. Depending on the timing, each check might trigger an overdraft exception and a stop-payment exception. If a check were large enough, it also would trigger a signature verification exception. Each of the three clerks involved would have only a partial picture, and each would have to locate the same paper check to complete the processing. In the end, the customer might be (incorrectly) charged with both a stop-payment fee and an overdraft fee. If the customer called to resolve the situation, there was no single person with all the relevant information who could handle the problem.

In an effort to surmount these shortcomings, Cabot Bank introduced check imaging and optical recognition software both upstairs in exceptions and downstairs in deposit processing in 1994. With check imaging, a high-speed camera makes a digital image of the front and back of each check as it passes through the reader-sorter, and the images can be stored on a central computer. Optical recognition software reads and stores check and deposit slip amounts. The new technology removed two major bottlenecks. First, paper checks no longer needed to be passed from one worker to another; the information on every check was simultaneously available to any authorized employee in either of the two departments. Second, it reduced the time that proof machine operators spent reading and recording the amounts on checks and deposit slips, an extremely labor-intensive task.

But this still left many tasks 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.

INCREASED SPECIALIZATION DOWNSTAIRS

In deposit processing, Cabot Bank managers reorganized tasks and jobs according to a standard template recommended by its imaging equipment vendor. Under the template, a check first goes to a preparation area where work-

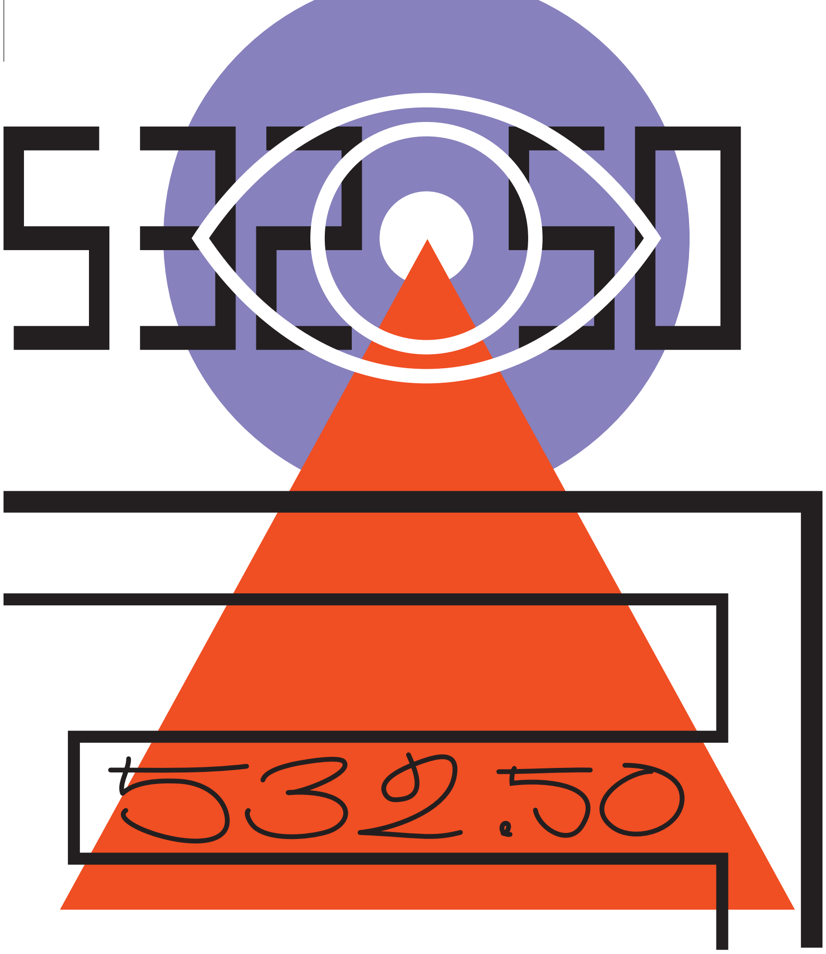
DOWNSTAIRS CHECK PROCESSING

The introduction of check imaging and optical recognition software reduced the number of employees downstairs from 67 to 53. It also resulted in more specialized jobs, with check preparers earning less than proof machine operators had, and image balancers and keyers earning more.

	TASKS			
	Prepare checks: remove staples and ensure checks face in same direction	Key in amount on checks with clear printing or handwriting	Decipher amounts on checks with poor handwriting and key in amount	Balance the deposit
1988				
Job title	Proof Machine Operator			
Hourly wage (1998$)	$10.03			
Number of FTE workers per million checks (Total employees=67)	67			
1998				
Job title	Check Preparer	Computer	Keyer	Image Balancer
Hourly wage (1998$)	$9.51	–	$10.00 + incentives	$11.00
Number of FTE workers per million checks (Total employees=53)	16	–	15	22

SOURCE: David H. Autor, Frank Levy, and Richard J. Murnane, "Upstairs, Downstairs: Computers and Skills on Two Floors of a Large Bank," *Industrial and Labor Relations Review*, April 2002.

ine tasks into separate jobs



ers remove paper clips and staples and make sure that all checks face in the same direction. Workers then deliver the checks to a machine that performs several processes: it magnetizes the ink on the MICR line, reads the check, sprays an endorsement and sequence number on the back, microfilms the front and back, and sorts it based on routing information. Finally, optical recognition software scans machine-printed and handwritten numeric amounts, identifies them, and stores the information. (As of 1999, the software successfully identified the amounts on about 57 percent of imaged checks.)

The template also includes processes for when a dollar amount cannot be recognized by the software. The check image is sent to the screen of a high-speed keyer who tries to identify the amount by looking at the numerical image on the right side of the check. If the high-speed keyer is still not sure of the amount, he or she passes 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. Once in the system, multi-check deposits are compared with deposit slips automatically. When discrepancies arise, a worker whose title is "image balancer" tracks the images electronically and performs the error detection and correction that was formerly done by the proof machine operator.

The resequencing of the tasks of deposit processing suggests that as computers reduced the cost of moving check information between workers, it became cheaper to divide the tasks previously performed by the proof machine operator into several specialized jobs. More specialized jobs led, in turn, to a modest increase in wage dispersion in the department; the wage for each job depended, in part, on the scarcity of the relevant skills within the workforce. Removing staples and ensuring that checks all face in the same direction are tasks that most adults with average eye-hand dexterity can accomplish with no training. The hourly pay for this job, $9.51, was the lowest in the bank's two departments and about 5 percent less than proof machine operators had made before the reorganization. (See table.)

Image balancing required somewhat scarcer skills. Like the proof machine operator, the image balancer must be able to figure out why some deposits do not balance. But 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 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. 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 image balancers was $11 per hour, 16 percent more than the rate for check preparers and about 10 percent more than proof machine operators had earned previously.

The department's highest wages were paid to the best keyers. The bank had an economic incentive to hire and reward workers who keyed rapidly, since this reduced the number of keying workstations the bank needed to purchase and maintain. While check preparers and image balancers were paid an hourly rate, keyers were also paid a bonus based on speed and accuracy. (Keying performances could now be monitored by computer, which simplified the determination of bonuses.) The best keyers earned $13.50 an hour, $2.00 per hour more than image balancers. This comparatively high wage reflected the relative scarcity of the skill of recognizing and recording check amounts extremely rapidly and accurately.

The introduction of computers into deposit processing led to the replacement of high school graduates by machines. The number of workers needed per million checks dropped from 67 to 53, and the share of departmental employees with an education beyond high school—primarily managers—increased. (Because acquisitions led to rapid growth in the number of checks processed, job reductions were accomplished without layoffs.) The substitution of machines for less-skilled workers is likely to increase as the character-

After the reorganization, upstairs clerks received exten

recognition software improves and more checks can be read by machine. Similarly, changes in regulations that permit banks to provide customers and banks with images of checks, rather than the checks themselves, may eliminate the jobs of many low-skilled workers who package checks for transit. Finally, since keyers no longer work with paper checks, there is no reason why they need to be located where the checks are digitized. Competitive pressure may push much of the less-skilled clerical work to low-wage, offshore locations, with significant job loss for less-educated workers in the parent plant. One bank, Sun Trust, recognizing that its keying operation outside Atlanta was particularly efficient, began transmitting images of checks from many sites around the country to Atlanta for keying.

INTEGRATING RESPONSIBILITIES UPSTAIRS

Upstairs in exceptions processing, the introduction of computer technology was handled differently. Managers believed that check imaging would produce large efficiency gains even with no other changes because employees would be able to spend less time searching for paper and more time resolving exceptions. But the vice president in charge of the department was determined to accomplish more. He thought that a broader reorganization of tasks and jobs could improve productivity and customer service, and result in better assignments using more skills. In his words: "fewer people doing more work in more interesting jobs."

He also believed that getting employees involved in the job redesign would use their knowledge and gain their commitment to the new system. Even before imaging technology was implemented, managers held focus groups asking workers about the aspects of their jobs that were irritating and seeking advice on changes that would make the jobs better. The consensus: work should be divided by customer account not exception type, and the same representative should deal with all exceptions—stop-payment requests, overdrafts, and so on—for a given account. In that case, a clerk who saw a stop payment order would be able to anticipate a possible (incorrect) overdraft exception as well as other exceptions from the same account. Although the reorganization would not be cost-free—employees would spend 80 hours in training (40 hours in the classroom and 40 hours on the job) to learn to handle the full range of exceptions—management accepted the plan.

While the new account-based workflow was designed in anticipation of check imaging, the bank began implemen-

UPSTAIRS EXCEPTIONS PROCESSING

As in routine processing, computer technology reduced employment dramatically (650 to 470). But previously separate jobs were redefined to be more integrated, training and pay rose, and Cabot started to recruit more college grads for the positions.

TASKS	Verify signatures on checks written for large amounts	Implement stop-payment orders	Handle overdrafts	Move check information from one clerk to another
1988				
Job title	Exceptions Processing Clerk	Exceptions Processing Clerk	Exceptions Processing Clerk	Exceptions Processing Clerk
Hourly wage (1998$)	$10.64	$10.64	$10.64	$10.64
Number of FTE workers per million checks* (Total employees=650)	98	98	424	30
1998				
Job title	Exceptions Processing Clerk			Computer
Hourly wage (1998$)	$13.50			–
Number of FTE workers per million checks (Total employees=470)	470			–

*Breakdowns by category are manager's estimates in 1994

SOURCE: David H. Autor, Frank Levy, and Richard J. Murnane, "Upstairs, Downstairs: Computers and Skills on Two Floors of a Large Bank," *Industrial and Labor Relations Review*, April 2002.

sive training and higher pay

tation before imaging technology came on line. The immediate result—a surprise to managers—was a major improvement in productivity. Before the reorganization, 650 workers processed the 65,000 exceptions each day; after the reorganization, this workload took only 530 workers. Given the productivity gains, we wondered why Cabot had not tried this earlier. Managers told us that Cabot had been focused on absorbing newly acquired banks and, therefore, had not considered such a reorganization. It is also possible that the reorganization of work became compelling only when managers knew that the gains would be enhanced by the additional savings that image processing made possible.

Once imaging was introduced, exceptions processing became even more efficient. Clerks no longer spent time shuffling paper checks or searching for a check when answering a query from a branch bank. One year later, the number of workers had fallen to 470, a 28 percent decline overall. Reorganization accounted for about two-thirds of productivity gains, new technology for the other third. Because the department had high turnover, staff reductions were achieved through attrition. As in deposit processing downstairs, almost all of the 180 positions eliminated were held by high school graduates.

In contrast to deposit processing, however, the reorganization in exceptions processing led to formerly specialized jobs being combined into broader ones. And since exceptions processing clerks now had more extensive training and could handle a wider variety of tasks—skills valued by Cabot's competitors—management decided it was prudent to pay higher wages. The average wage for lower-level, nonsupervisory workers rose from $10.64 an hour in 1988 to $13.50 in 1998. Most workers were also moved up a pay grade after they completed training. In addition, management steadily increased the proportion of employees they classified as "exempt," that is, workers who were required to work independently, show initiative, or supervise others. Before the reorganization, 20 percent of the unit's workers were exempt; by 1998, the number was 35 percent.

Management also expanded the range within each pay grade. For example, grade 23—a grade to which many representatives were initially assigned—had a 1993 range of $17,800 to $26,300 but a 1998 range of $18,900 to $37,100. The greater pay range reflected the firm's belief that employees had greater scope for judgment and initiative in the redesigned job. In particular, management wanted to motivate employees not only to do their own complex jobs well, but also to recommend additional design improvements. Said the vice president, "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." Although expanding the pay range may simply have reflected external market forces that were leading to greater wage dispersion throughout the economy, there was no comparable expansion within each pay grade downstairs in deposit processing.

Also somewhat different was the response to the demand for higher skills that the reorganization engendered. Although training went a long way, particularly in imparting the relevant computer skills, many managers upstairs found that the ability to "see the whole picture" was difficult to teach. Accordingly, Cabot restructured its recruiting process in exceptions processing to identify job candidates with a history of taking initiative and problem solving. For example, they asked prospective hires to describe problems they had encountered in previous jobs or in school and how they resolved them. Candidates were also interviewed by supervisors from several groups and could only be employed if multiple supervisors vetted the hire. In the words of one manager, "[recruits] have to be right for the whole bank."

Managers in exceptions processing reported that the new recruiting process favored applicants who had at least some college education. Had managers retained the narrow task structure, computerization certainly would have eliminated the jobs of many high school workers engaged in the "paper chase." But the broader job responsibilities also spurred managers to recruit college graduates into the department, something they had not done before.

Was the new job design inevitable? Seemingly not, at least in the short run. Management had considerable discretion to either broaden the exceptions processing job or leave the previous job design intact. Some banks have kept jobs in exceptions processing specialized by function, even after introducing check imaging. Not enough time has elapsed to judge whether the different ways of organizing work in exceptions processing reflect equally productive ways of organizing the tasks, or whether competition will reveal that one way is more efficient than others. But we suspect that Cabot Bank's choice effectively takes advantage of the interdependencies among exceptions-processing tasks and will be rewarded by the market in the long run.

CONCLUSION

So why did things at Cabot turn out one way downstairs and another way upstairs? Research by Professor Assar Lindbeck of Stockholm University and Dennis Snower of the University of London suggests that managers combine tasks into broader jobs when the tasks are complementary and create single-task jobs that take advantage of specialization when they are not—for example, in Adam Smith's pin factory. It seems likely that the reason new technology resulted in narrower job definitions in the Deposit Processing Department downstairs at Cabot Bank is that there was little complementarity among the tasks. Once imaging reduced the cost of moving check information from one worker to another, it made sense to exploit economies of specialization. On the other hand, complementarity among tasks in the Exceptions Processing Department upstairs made task integration attractive.

This appears not to have been the only consideration, however. Upstairs managers also seemed to have the explicit goals of making jobs more interesting and in involving the workers in the redesign. MIT Professor Paul Osterman has pointed out that where managers care about the quality of customer service and the well-being of employees, we tend to see integrated job designs. ❋

David H. Autor, is assistant professor at the MIT Department of Economics, and the National Bureau of Economic Research; Frank Levy is professor at the MIT Department of Urban Studies and Planning; and Richard J. Murnane is professor at the Harvard Graduate School of Education, and the National Bureau of Economic Research. This article is based on "Upstairs, Downstairs: Computers and Skills on Two Floors of a Large Bank," published in the *Industrial and Labor Relations Review*, April 2002.

letter from Jaffrey, New Hampshire

Business is kabooming

By Jane Harrigan § Begin with a glittering silver chrysanthemum, 1,000 feet wide, exploding over the Washington Monument on the Fourth of July. Proceed to Boston, where, with each cymbal crash of the "American Symphony," the pistils of giant red flowers strobe 1,000 feet above the Charles River. Take your pick of 700 other fireworks displays from Miami to Minnesota to Montreal. If you could follow a string of colored stars from all these productions back to their source, the trail would end at a tan, brick, and metal building on a rural road in southwestern New Hampshire. Here, behind a door guarded by jade lions, the 22 employees of Atlas PyroVision Productions choreograph the displays that illuminate the nation.

Here in Jaffrey, population 5,500, handmade shells designed to Atlas's specifications arrive from Spain and Japan and China and accumulate in three concrete-walled magazines holding 60,000 pounds of explosives each. Here, the latest computer equipment calibrates the precision firing of a crude product that has changed little since the Chinese invented gunpowder over 1,000 years ago. Here, Stephen Pelkey,