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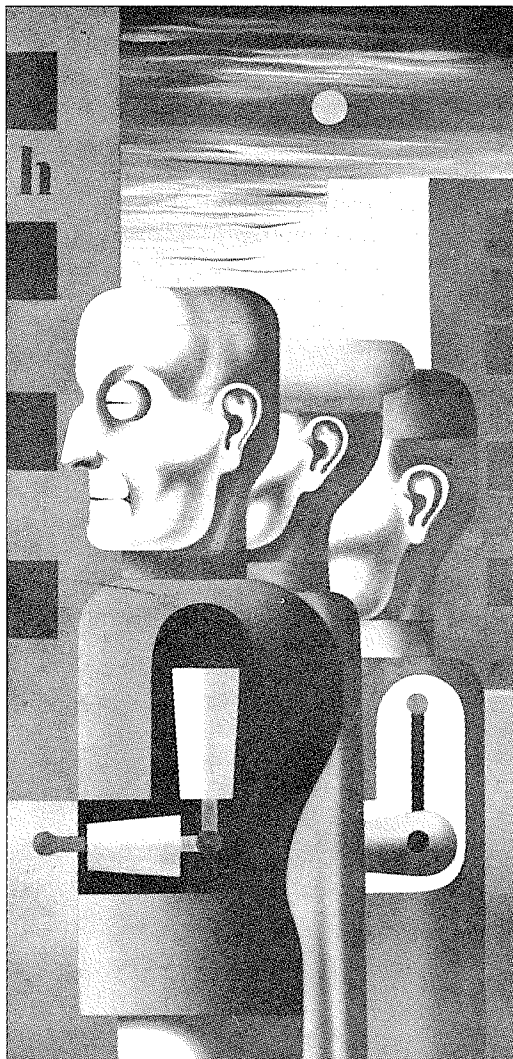
# TECHNOLOGY'S REVENGE

BY PAUL KRUGMAN

In his science-fiction novel of 1952, *Player Piano*, Kurt Vonnegut imagined a future in which the ingenuity of engineers has allowed machines to eliminate virtually all manual labor. The social consequences of this technological creativity, in his vision, are disastrous: Most people, instead of finding gainful employment, live on the dole or are employed in pointless government make-work programs. Only the most creative and talented can find meaningful work, and their numbers steadily shrink as more and more jobs are automated out of existence.

For the first 20 years after *Player Piano* appeared, it seemed that Vonnegut could not have been more wrong. Between World War II and the early 1970s, the world's advanced economies were spectacularly successful at creating precisely the kind of employment that he imagined automation would destroy: well-paying jobs for workers of average skills and education. Social observers waxed eloquent over the unprecedented prosperity of the working class. Thanks to the 30-year "Go-Getter Bourgeois business boom," writer Tom Wolfe announced, "the word *proletarian* can no longer be used in this country with a straight face." Economists, who had always regarded most fears about automation as nonsense, felt confirmed in their dismissal of the issue.

But the past 20 years have not been good ones for ordinary workers. Even as the earnings of many college-educated workers soared in the United States, young men



Maschinenmänner (1930), by Heinrich Hoerle

without college degrees have seen their real wages drop by 20 percent or more—this in spite of productivity growth which, while disappointing, nonetheless allowed the average American worker to produce about 25 percent more in 1993 than in 1973. In Europe, the growth of wage inequality has been less dramatic, but there has been a

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steady, seemingly inexorable rise in unemployment, from less than three percent in 1973 to more than 11 percent today (versus six percent in the United States).

Many economists believe that the American and European experiences are two sides of the same coin. For whatever reason, employers have been increasingly reluctant to pay for the services of those who do not offer something exceptional. In the United States, where unemployment benefits are relatively skimpy and of relatively short duration (26 weeks), and where the unemployed often find themselves without health insurance, workers have little choice but to accept jobs no matter how low the pay. Thus, U.S. labor markets have been, in the fine euphemism of official documents, "flexible." In Europe, much more generous social benefits make it easier for workers to turn down jobs they find unacceptable, and various government regulations and restrictions make employers less willing and able to offer low-wage jobs in any case. Thus, the same forces that lead to less pay for the less skilled in the United States lead to rising unemployment for the same group in Europe. The larger outcome is the same on both sides of the Atlantic: The broad equality of economic outcomes that the postwar West had come to take for granted seems to be receding into memory.

Most people who read intellectual magazines or watch public television know why this is happening. Growing international competition, especially from low-wage countries, is destroying the good manufacturing jobs that used to be the backbone of the working class. Unfortunately, what these people "know" happens to be flatly untrue. The real reason for rising wage inequality is subtler: Technological change since 1970 has increased the premium paid to highly skilled workers, from data processing specialists to physicians. The big question, of course, is whether this trend will continue.

Before we can get to that question, how-

ever, it is necessary to clear away some of the underbrush. Much public discussion of jobs—even among people who consider themselves sophisticated and well-informed—has been marked by basic misunderstandings of the facts. Consider this statement: "Modern technologies of transportation and communication make it possible to produce anything anywhere. This technological shrinking of the world has only been reinforced by the fall of communism, which has made the Third World safe for multinational corporations. As a result, a massive redeployment of capital and technology from the high-wage countries of the West to low-wage developing nations is now occurring. This redeployment of capital along with the flood of low-cost imports is destroying the well-paying manufacturing jobs that used to support a large middle class in the United States and Europe. In short, globalization favors Western capital, but it is devastating to Western labor."

**C**onvincing as this may sound, the statement is specious. In fact, I made it up to illustrate a view of the world that passes for sophistication among many policy intellectuals but is almost completely refuted by the available evidence.\*

At the basic level, this conventional view suggests that capital and technology are in fixed supply, and that growth in new countries necessarily comes at the expense of the more established countries. The reality is that the diffusion of technology, while it increases competition faced by the leaders' exports, also expands their markets and reduces the price of their imports. For example, the United States must buy virtually all of its laptop computers from foreign producers, but the growth of overseas produc-

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\*For a fuller discussion of this point, see my article in the *Harvard Business Review* (Summer 1994). In a comprehensive survey of the literature on job creation, *High and Persistent Unemployment: Assessment of the Problem and its Causes* (1993), economist Jørgen Elmeskov flatly concludes that "trade seems an unlikely prime candidate for explaining increased unemployment."

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tion has enlarged markets for U.S.-made microprocessors and cut the price of laptops. In principle, the net result of the diffusion of technology could be either to raise or to lower First World income. In practice, there is little discernible effect.

Nor is the world supply of capital a fixed quantity. As countries grow, they also save—in the case of rapidly growing Asian nations, they save at astonishing rates. Third World growth may thus add to the world supply of capital as fast as or faster than it increases the demand.

Moreover, the amount of imports arriving from newly industrializing countries and the size of capital flows going to them fall far short of what is suggested in alarmist rhetoric. If there is a single piece of knowledge that separates serious international economists from fashionable popularizers, it is a sense of *how big* the world economy really is. We have all heard enough stories of particular factories that have moved to Mexico or Indonesia to form the impression that a massive global trend is underway. But even a billion-dollar investment is insignificant amid the sheer immensity of the economies of the industrialized nations. Their combined gross domestic products in 1990 exceeded \$19 trillion, and their combined domestic investment exceeded \$4 trillion. The total movement of capital to newly industrializing countries in 1993—a record year, unlikely to be surpassed in 1994—was roughly \$100 billion. That is, less than 2.5 percent of the investment of the First World actually flowed south. While it is true that tens or even hundreds of thousands of workers in advanced countries have lost their jobs to low-wage imports, the total labor force in the industrialized world is more than 400 million strong; almost every effort to quantify the reasons why more than 30 million of these workers do not have jobs

finds that Third World competition plays little if any role. That is not to say that international trade and capital mobility could not have a more important impact in the future. But declining wages and rising unemployment are not things that might happen once globalization really gets going; they are trends that have been in progress for 20 years. What is causing them?

**E**conomists use the word “technology” somewhat differently from normal people. *Webster’s* defines technology as “applied science,” which is pretty much the normal usage. When economists speak of technological change, however, they mean any kind of change in the relationship between inputs and outputs. If, for example, a manufacturer discovers that “empowering” workers by giving them a voice in how the factory is run improves quality—and allows the plant to employ fewer supervisors—then in the economic sense this would be an improvement in the technology, one that is biased against employment of managers. If, however, a manufacturer discovers that workers will produce more when there are many supervisors constantly checking on them, this is also a technological improvement, albeit one biased toward employment of managers.

In this economist’s sense, it seems undeniable that over the past 20 years the advanced nations have experienced technological change that is strongly biased in favor of skilled workers. The evidence is straightforward. The wages of skilled workers, from technicians to corporate executives, have risen sharply relative to the wages of the less skilled. In 1979, a young man with a college degree and five years on the job earned only 30 percent more than one with similar experience and a high school degree; by 1989, the premium had jumped

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## America's Fastest Growing Occupations, 1992–2005

(In parentheses: the number of projected new jobs, in thousands)

	Percent change
Home health aides (479)	138
Human services workers (256)	136
Personal and home care aides (166)	130
Computer engineers and scientists (236)	112
Systems analysts (501)	110
Physical and Corrective therapy assistants and aides (57)	93
Physical therapists (79)	88
Paralegals (81)	86
Teachers, special education (267)	74
Medical assistants (128)	71
Detectives, private (41)	70
Correction officers (197)	70
Child care workers (450)	66
Travel agents (76)	66
Radiologic technologists and technicians (102)	63
Nursery workers (44)	62
Medical records technicians (47)	61
Operations research analysts (27)	61
Occupational therapists (24)	60
Legal secretaries (160)	57
Teachers, preschool and kindergarten (236)	54
Manicurists (19)	54
Producers, directors, actors, and entertainers (69)	54
Speech-language pathologists and audiologists (37)	51
Flight attendants (47)	51
Guards (408)	51

Source: U.S. Bureau of Labor Statistics

*The fastest growing occupations in percentage terms are not necessarily those that will produce the largest number of new jobs. The most growth in absolute terms will occur in the retail sales clerk category, which will grow by 786,000 jobs (21 percent) between 1992 and 2005.*

to 74 percent. If the technology of the economy had not changed, this sharp increase in the relative cost of skilled workers would have given employers a strong incentive to cut back and substitute less-skilled workers where they could. In fact, exactly the opposite happened: Across the board, employers *raised* the average skill level of their work forces.

It is hard not to conclude that this technologically driven shift in demand has been

a key cause of the growth of earnings inequality in the United States as well as much of the rise in unemployment in Europe. It is not the only possible explanation. It could have been the case that rising demand for skilled workers was not so much the result of greater demand for skill within each industry as of a shift in the mix of industries toward those sectors that employ a high ratio of skilled to unskilled workers. That sort of shift could, for example, be the result of

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## Who Creates Jobs?

**T**he U.S. economy may have failed to produce rising wages during the past 20 years, but it has been a prodigious creator of new jobs. Since 1980, the nation has gained some 20 million net (after subtracting those that were lost) new jobs, and payrolls continue to grow at an impressive rate. But who is creating those jobs—and how good the jobs are—has been the subject of a sometimes rancorous and ideologically charged debate. Do small, supercharged entrepreneurial firms deserve most of the credit, or do brand-name big businesses?

David Birch, then an MIT researcher, fired the debate's first shots in a series of studies beginning in the late 1970s. Small businesses (with fewer than 100 employees), he declared in a 1981 article in the *Public Interest*, were responsible for 80 percent of all new jobs between 1969 and 1976. The implications, Birch said, were clear. Policies aimed at helping small business, such as targeted tax breaks and regulatory relief, would do a lot more to put Americans to work than broad-gauged stimulus measures such as general tax incentives, easy money, and public works programs. The message went over well in the entrepreneur-oriented America of the 1980s, especially among many conservatives. But many liberals did not like hearing that small business—generally nonunion, difficult to regulate, and conservative in its politics—might be the key to national prosperity.

Birch's argument promptly touched off a battle of the data bases among researchers, as various critics attacked his data and methods. There was plenty to criticize. In his early

research, for example, Birch did not take account of the fact that many firms that seem small are actually units of much-larger parent companies. Even the U.S. Small Business Administration claimed in 1983 only that smaller companies created 56 percent of all jobs.

In *Employers Large and Small* (1990), economists Charles Brown, James Hamilton, and James Medoff (using a different data base, with a few flaws of its own) pointed out that small business's share of total employment did not grow at all between 1958 and 1982. Even today, according to government data, firms with fewer than 100 workers employ about one-third of all Americans in the labor force; those with fewer than 500 employ about half of all workers. What seems to happen, critics such as Brown, Hamilton, and Medoff say, is that smaller firms create a lot more jobs than big companies do—especially through start-ups—but they are jobs with a high mortality rate.

For once, however, ideological smoke and fire seem to be leading toward a measure of illumination. Birch and his critics now seem to be moving toward a consensus on some important points. As Birch put it recently in a report co-authored with Anne Haggerty and William Parsons for his Cognetics, Inc., consulting firm, "The closer you look, the more useful it becomes to describe firms, not in terms of how big they are, but in terms of what they are doing." These and other researchers now find that it is not the smallest firms that produce the most jobs but, as common sense would suggest, the firms that grow the fastest. Between 1989 and

increased trade with labor-abundant Third World countries. But in fact the overwhelming evidence is that the demand for unskilled workers has fallen not because of a change in *what* we produce but because of a change in *how* we produce.

Is it really possible for technological

progress to harm large numbers of people? It is and it has been. Economic historians confirm what readers of Charles Dickens already knew, that the unprecedented technological progress of the Industrial Revolution took a long time to be reflected in higher real wages for most workers. Why? A likely answer is

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1993, according to calculations by Birch and his colleagues, a mere three percent of all American businesses generated 4.4 million net new jobs—virtually all of the jobs they believe were created during this period. Most of these “Gazelles,” as the authors call the job generators, are small, but only a minuscule fraction of small businesses are Gazelles. “Most small firms grow slowly,” Birch and his colleagues say.

The size issue is complicated by the fact that the larger Gazelles are the biggest job producers. In 1989, only three percent of the Gazelles had 100 or more employees, but they were responsible for 44 percent of all the new Gazelle jobs generated by 1993.

Finally, Gazelles are spread throughout the economy. They are not concentrated in “hot” areas such as finance or biotechnology, Birch, Haggerty, and Parsons note, but exist wherever people with new ideas and technologies “find a better way of doing things in their particular kind of firm—be it fish wholesaling, dental insurance, discount brokerage, lumber yards, or low-price outlets.”

But are these “good” jobs? Birch and his colleagues insist that they are. After all, they point out, the emerging growth companies tend to rely on new technologies, and so they need highly skilled (and highly paid) workers. It is a myth, moreover, that bigger payrolls equal bigger paychecks. Many large firms, from hospitals to department stores, pay mediocre wages. The nation’s relatively high-paying big manufacturers, basically the Fortune 500, employ only about five percent of all U.S. workers.

It is true, Birch and his colleagues write, that a somewhat higher proportion of the

new jobs created by small, fast-growing companies during the 1989–93 period paid low wages. But after taking account of the effects of layoffs and shutdowns, these younger firms were bigger net creators of “good” jobs. Indeed, they created 1.4 million net new “good” jobs while big companies *eliminated* a net of 2.5 million.

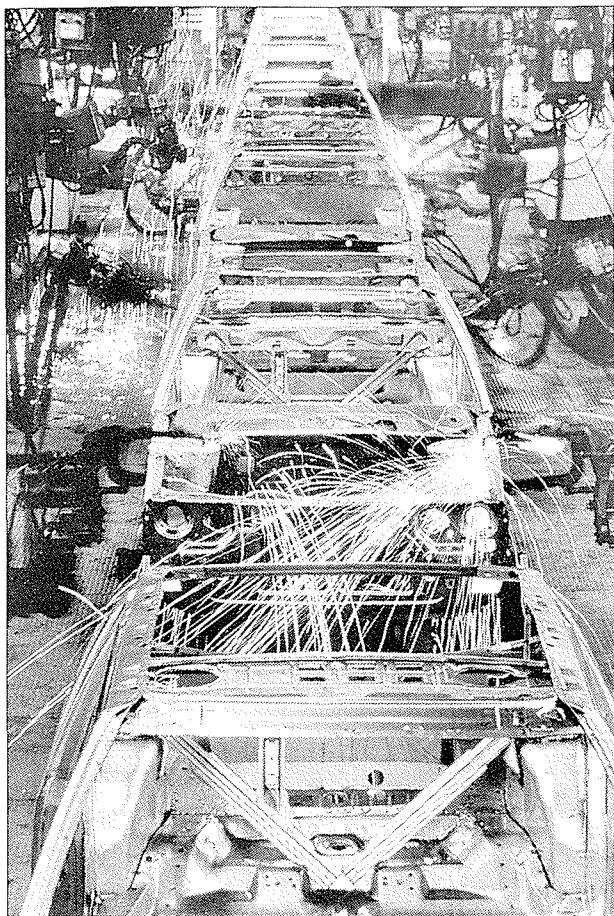
The debate over good jobs is certain to continue. Critics are sure to point out, for example, that Birch’s latest study covers a period of economic stagnation. Perhaps big firms will perform better as the economy turns up. And Birch’s study says nothing about benefits. In general, larger employers are more likely to provide such things as health insurance.

**M**eanwhile, an entirely new front in the big-versus-small debate has been opened by Bennett Harrison in his new book, *Lean and Mean* (1994). Harrison, a political economist at Carnegie Mellon University, takes aim not only at the statistical findings of Birch and his allies but at the whole “romantic belief in the significance of atomistic, small enterprise . . . in a modern industrial economy.” He insists that many of today’s small firms are simply creatures—by virtue of contracts or handshakes—of newly “lean and mean” big corporations. Big business still dominates the world economy, Harrison says, surviving by letting smaller players who offer smaller paychecks take over many of its peripheral functions. And in the rise of this “networked” corporation, Harrison contends, lies the source of the growing income inequality in the United States during the past 20 years.

that early industrial technology was not only labor saving but strongly capital using—that is, the new technology encouraged industrialists to use less labor and to invest more capital to produce a given amount of output. The result was a fall in the demand for labor that kept real wages stagnant for perhaps 50 years,

even as the incomes of England’s propertied classes soared.

Economists more or less agree that the same thing is happening to the Western world today, except that the benefits of biased technological change are flowing not to capital but to the highly skilled.



American industry is producing more with fewer workers: Two million manufacturing jobs disappeared between 1988 and '93.

It is easy to understand why the Industrial Revolution was capital using and labor saving. Just think of a factory full of power looms replacing thousands of hand weavers—the development that gave rise to the Luddite rebellion in early-19th-century Britain. Can we come up with comparable images that relate recent technological change in the economist's sense to its more normal usage? That is, what is changing in the way that we produce goods and service that has apparently devalued less-skilled workers?

The short answer is that we do not know. There are, however, several interesting stories and pieces of evidence.

Probably the simplest story about how

modern technology may promote inequality is that the rapid spread of computers favors those who possess the knowledge needed to use them effectively. Anecdotes are easy to offer. Economist Jagdish Bhagwati cites the "computer with a single skilled operator that replaces half a dozen unskilled typists." Anecdotes are no substitute for real quantitative evidence, but for what it is worth, serious studies by labor economists do suggest that growing computer use can explain as much as one-half of the increase in the earnings edge enjoyed by college graduates during the 1980s.

Yet there is probably more to the story. The professions that have seen the largest increases in incomes since the 1970s have been in fields whose practitioners are not obviously placed in greater demand by computers: lawyers, doctors, and, above all, corporate executives. And the growth of inequality in the United States has a striking "fractal" quality: Widening gaps *between* education levels and professions are mirrored by increased inequality of earnings *within* professions. Lawyers make much more compared with janitors than they did 15 years ago, but the best-paid lawyers also make much more compared with the average lawyer. Again, this is hard to reconcile with a simple story in which new computers require people who know how to use them.

One intriguing hypothesis about the relationship between technology and income distribution, a hypothesis that can explain why people who do not operate computers or fax machines can nonetheless be enriched by them at the expense of others, is the "superstar" hypothesis of Sherwin Rosen, an economist at the University of Chicago. Almost 15 years ago, before the explosion of inequality had become apparent, Rosen argued in the *Journal of Political Economy* that communication and information technology extend an individual's

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span of influence and control. A performance by a stage actor can be watched by only a few hundred people, while one by a television star can be watched by tens of millions. Less obviously, an executive, a lawyer, or even an entrepreneurial academic can use computers, faxes, and electronic mail to keep a finger in far more pies than used to be possible. As a result, Rosen predicted, the wage structure would increasingly come to have a "tournament" quality: A few people, those judged by whatever criteria to be the best, would receive huge financial rewards, while those who were merely competent would receive little. The point of Rosen's analysis was that technology may not so much directly substitute for workers as multiply the power of particular individuals, allowing these lucky tournament winners to substitute for large numbers of the less fortunate. Television does not take the place of hundreds of struggling standup nightclub comedians; it allows Jay Leno to take their place instead.

**W**ill technology continue to favor a few lucky people over the rest, or will the last quarter of the 20th century turn out to have been a transitory bad patch for the common man? At first sight, it seems obvious that the progress of technology must lead to an ever-growing premium on skill. How could it be otherwise in an era when sophisticated computers and information systems are becoming ever more crucial to our economy? Isn't it obvious that the only good jobs will be for those who possess exceptional intellectual talent and skills—those who, in the phrase of Secretary of Labor Robert Reich, are able to work as "symbolic analysts"?

History teaches us, however, that merely assuming a continuation of recent trends is often very misleading. Technology is less like a railroad track than a spiral staircase, with many reversals of direction along its upward path. The long-term effect of the Industrial Revolution is a case in point. To Victorian futurists, it seemed obvious that the capital-us-

ing bias of industrial technology would continue indefinitely, bringing with it an ever-greater gulf between the owners of capital and the working class. In *The Time Machine* (1895), H. G. Wells forecast a future in which workers have been reduced to subhuman status. These Victorians were wrong—indeed, if Wells had possessed the kind of data available today, he would have known that wages had begun to rise again long before he wrote his novel. During the 20th century, capital has claimed a declining share of the national income and labor has taken a growing share.

**T**echnological advance, moreover, does not always increase the need for skilled labor. On the contrary, in the past one of the main effects of mechanization was to reduce the special skills required to carry out many tasks. It took considerable skill and experience to weave cloth on a hand loom, but just about anybody could learn to tend a power loom. What is true is that, to date, technological progress has consistently tended to increase the demand for a particular kind of skill, the kind that is taught in formal education and is most easily acquired by the kind of person who does well in formal education. Two centuries ago, only a minority of jobs required literacy; one century ago, only a few jobs required anything like a modern college education. Nowadays higher education is not a luxury for the wealthy but something intensely practical, a virtual necessity for the career minded.

But it is not at all clear that this trend will continue indefinitely. There is no inherent reason why technology cannot be "college-education saving" rather than college-education using. It is possible to see examples of how this might occur even today. This essay, for example, was written using a newly acquired word processor. I did not bother to read the manual; the graphical interface, with its menus of icons, usually makes it obvious how to do what I want, and I can easily call up on-screen help with the push of a button if I get lost. Whenever we use the term "user-friendly," we



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are implying that we have a production technique that requires less skill than it used to.

But isn't this kind of reversal always going to be the exception rather than the rule? Not necessarily. In fact, I would make a speculative argument that in the long run technology will tend to devalue the work of "symbolic analysts" and favor the talents that are common to all human beings. After all, even the most brilliant specialists are actually rather poor at formal reasoning, while even the most ordinary person can carry out feats of informal information processing that remain far beyond the reach of the most powerful computers. As the artificial intelligence pioneer Marvin Minsky points out, "A 1956 program solved hard problems in mathematical logic, and a 1961 program solved college-level problems in calculus. Yet not until the 1970s could we construct robot programs that could see and move well enough to arrange children's building blocks into simple towers. . . . What people vaguely call common sense is actually more intricate than most of the technical expertise we admire." Chess-playing programs are not yet quite good enough to beat the world's greatest players, but they are getting there; a program that can recognize faces as well as a two-year-old can remains a distant dream.

Rereading *Player Piano* recently, I found the totally automated factories Vonnegut imagined more than 40 years ago completely credible, but found myself wondering who cleans them (or for that matter the houses of his industrial elite)? It is no accident that no description is given of how these mundane tasks are

automated—because as Vonnegut must have sensed, it will be a very long time before we know how to build a machine equipped with the ordinary human common sense to do what we usually regard as simple tasks.

So here is a speculation: The time may come when most tax lawyers are replaced by expert systems software, but human beings are still needed—and well paid—for such truly difficult occupations as gardening, house cleaning, and the thousands of other services that will receive an ever-growing share of our expenditure as mere consumer goods become steadily cheaper. The high-skill professions whose members have done so well during the last 20 years may turn out to be the modern counterpart of early-19th-century weavers, whose incomes soared after the mechanization of spinning, only to crash when the technological revolution reached their own craft.

I suspect, then, that the current era of growing inequality and the devaluation of ordinary work will turn out to be only a temporary phase. In some sufficiently long run the tables will be turned: Those uncommon skills that are rare because they are so unnatural will be largely taken over or made easy by computers, while machines will still be unable to do what every person can. In other words, I predict that the current age of inequality will give way to a golden age of *equality*. In the very long run, of course, the machines will be able to do everything we can. By that time, however, it will be *their* responsibility to take care of the problem.