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Technical Change and the Dispersion of Wages

In the last 25 years, the wage gap in the U.S. between highly skilled and less skilled workers has widened noticeably. For example, in 1975 the gap in average annual earnings between high school graduates and non-graduates was 26%; by 1999, the gap was 52%. The gap widens even more when comparing workers with advanced degrees and those with relatively little education. This rise in inequality has led to considerable debate about the underlying causes. This *Letter* reviews some of the evidence on this issue and discusses some recent explanations relating these phenomena to another development that has been much in the news recently, namely, an increase in the pace of technical progress.

What the data show

Figure 1 shows relative annual earnings from 1975 to 1999 for U.S. workers divided according to five categories of educational levels; educational levels commonly proxy for skill levels, which are hard to measure directly. (Note that these data are from the Census Bureau, which redefined the groups in 1991 to focus on degrees earned rather than years in school; this definitional change does not alter the basic message of the data, but it does alter the relative size of each group, as will be discussed below.) To focus more closely on the changes in the dispersion of earnings over time, these data have been normalized to equal 100 in 1975. While wages in all five categories rose over the sample, the wages of skilled workers rose noticeably more than those of less skilled workers. (These results are confirmed by a detailed analysis of the data; see, for instance, the influential study by Juhn, Murphy, and Pierce 1993.)

The distribution of wages depends on the supply of different kinds of workers relative to the demand for them. For instance, the relative wages of workers who did not complete high school could have declined if the number of people in this category had risen relative to the others. Figure 2 presents evidence against this explanation; it plots the number of workers in the same five categories and again shows data normalized to 100 in 1975. The number of workers who did not finish high school actually *fell* by about a third over this period, while the

Figure 1
Earnings

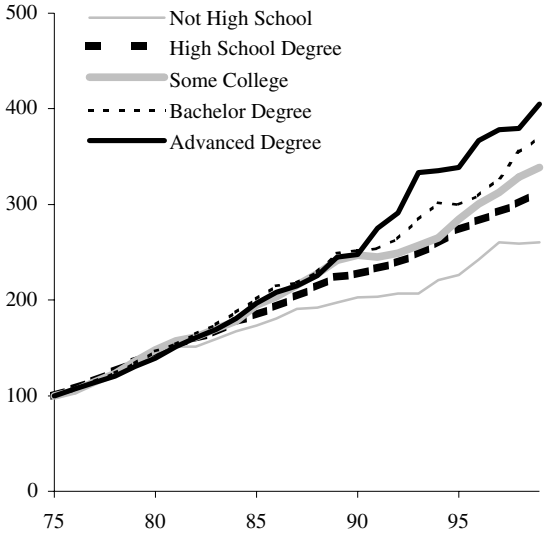
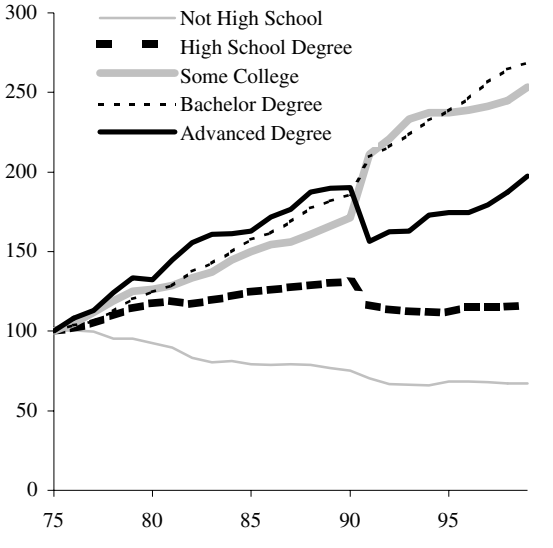


Figure 2
Number of workers



number of workers with college degrees grew to more than 2½ times its original size, and the number of workers with advanced degrees doubled. (The figure suggests that these ratios would have been different in the absence of the change in the Census Bureau methodology in 1991; for our purposes the most important characteristic of the data is that the series moved in the same direction both before and after the change in methodology.)

The fact that skilled workers' wages increased at the same time that their number increased suggests that an increase in demand was the dominant force behind the rising dispersion of wages in the data. Of course, the supply of skilled labor could have risen independently of any increase in demand; however, the wage data imply that the demand for skilled labor has gone up by more than whatever increase in supply might have taken place. The remainder of this *Letter* discusses research that assigns a prominent role to technical change when accounting for this increase in demand. Since the amount of research on this issue is too large to be addressed in this *Letter,* I will focus on some recent work and try to provide a flavor of the rest.

Technology as first cause

Several studies have developed models and documented evidence to show that the observed increase in wage dispersion has been driven by technical change. Griliches (1969) presented one of the key concepts for studying these issues. He assumed the existence of two kinds of labor, skilled and unskilled, and posited that capital and skilled labor were "complements." While this term has a precise technical meaning, for our purposes the key implication is that an increase in the capital stock raises the productivity of a skilled worker more than that of an unskilled worker. Given this assumption, an increase in the stock of capital raises the demand for skilled workers relative to unskilled workers and so pushes up the wages of the former relative to the latter.

Based on this work, Krusell, et al. (2000) develop a model to carry out a quantitative analysis of the skill premium (which is defined as the average wage of skilled workers relative to that of unskilled workers). They argue that steady improvement in the quality of capital equipment over their 1963–1992 sample has led to a secular decline in the price of this equipment relative to other goods in the economy. (Consider, for example, how the price of computers has fallen relative to the price of haircuts.) Since capital goods and skilled labor are complements, this has pushed up the demand for skilled labor and, hence, pushed up the skill premium. Further, there is evidence that the pace of decline of the relative price of capital has picked up since the 1970s, which means that the skill premium has been pushed up even further.

After defining skilled labor as workers who have at least 16 years of education, they find that the capital-skill complementarity effect raised the skill premium by roughly 60% over their sample. The contribution of this component was particularly marked during the 1960s, when it raised the skill premium by an average of 2.5% per year, and after 1980, when it raised the premium by about 2.1% per year. They also show that in the absence of the capital-skill complementarity effect, the increase in the relative supply of skilled labor observed over the 1963–1992 period would have pushed the skill premium down by about 40%.

Greenwood and Yorukoglu (1997) emphasize a somewhat different channel through which technical progress affects wage dispersion. According to their hypothesis, skilled workers are able to learn how to work with new technologies more easily than unskilled workers. Therefore, periods of rapid technical progress lead to an increase in the demand for skilled workers, which pushes up the skill premium. Note that this hypothesis implies that the rise in the skill premium that accompanies the introduction of a new technology will be temporary; as time goes by, relatively low skilled workers will learn how to work with the new technologies as well, and the skill premium will dissipate. Thus, wage dispersion should fall back over time.

In their model, each vintage of capital embeds the latest technology. An increase in the pace of technical progress raises investment in capital goods. Because skilled workers are needed to operate the new plants, every 1% increase in the capital-equipment ratio pushes up the ratio of skilled to unskilled employment by 2.5%. As the plant ages, it is no longer profitable to hire as many skilled workers. Greenwood and Yorukoglu find that an increase of one year in the age of the plant reduces the share of skilled labor in the total wage bill by roughly 0.6%.

Labor supply as first cause

The research we have discussed so far explains the increase in the dispersion of wages and in the number of skilled workers as a response to a change in technology. Another strand of the literature points out that innovation responds to economic incen-

tives and presents models where changes in the supply of labor trigger changes in technology and relative wages.

According to Kiley (1999), an economy with a larger share of skilled labor offers greater incentives for developing skill-biased technologies than an economy with a smaller share. Entrepreneurs respond to this larger market by developing technologies that can take advantage of this skilled labor pool. The invention of these new technologies pushes up the demand for skilled labor and ends up raising the relative wages of skilled labor. Kiley also shows that an increase in the supply of skilled workers leads to the creation of more skill-biased technologies and raises the relative wages of skilled workers in the long run. The pattern of technical change since the mid-1970s and the rising dispersion of wages in the U.S. is then explained as a response to an increase in the relative supply of labor since the 1970s, "…at least in part exogenously due to government support for higher education." (p. 720)

Acemoglu (2002) agrees with Kiley, arguing that one can understand technical change over a long span of time by recognizing that the development and use of technology respond to profit incentives. In one particularly interesting example, he points out that there was a large increase in the supply of unskilled labor in English cities during the late nineteenth century. Among the factors responsible for this change were rapid population growth in England, a large influx of labor from Ireland, as well as a substantial release of labor from agriculture due to various factors. Acemoglu argues that this led to a major increase in skill-replacing technologies, "…most notably the factory system replacing tasks previously performed by skilled artisans" (p. 42). He also cites some historians who have pointed out that the absence of cheap labor may have hampered the adoption of the factory system in the U.S. during this period. The twentieth century represents a sharp contrast to the nineteenth, as the supply of skilled labor has gone up rapidly, and this has led to an increase in skill-biased technical change. Taken together, these two cases show that there is no reason to believe that technical change tends to favor either highly skilled or low-skilled labor; instead, the kind of change that takes place depends upon the opportunities facing innovators.

A tentative assessment

While economists have pointed to other factors that may have contributed to the increased dispersion of wages we have seen over this period, available evidence does suggest that an increase in the demand for skilled labor that is related to recent technical change has played a significant role. It is harder to determine how much is explained by theories that emphasize an exogenous increase in labor supply as a first cause; while these theories are appealing, there is little evidence yet on their quantitative importance. Finally, from the perspective of the debate on wage dispersion, it will be interesting to observe how the distribution of wages changes if, and when, the recent burst in innovation tapers off.

Bharat Trehan
Research Advisor

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