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INFORMATION TECHNOLOGY INCREASES EARNINGS DIFFERENTIAL AND DRIVES NEED FOR EDUCATION

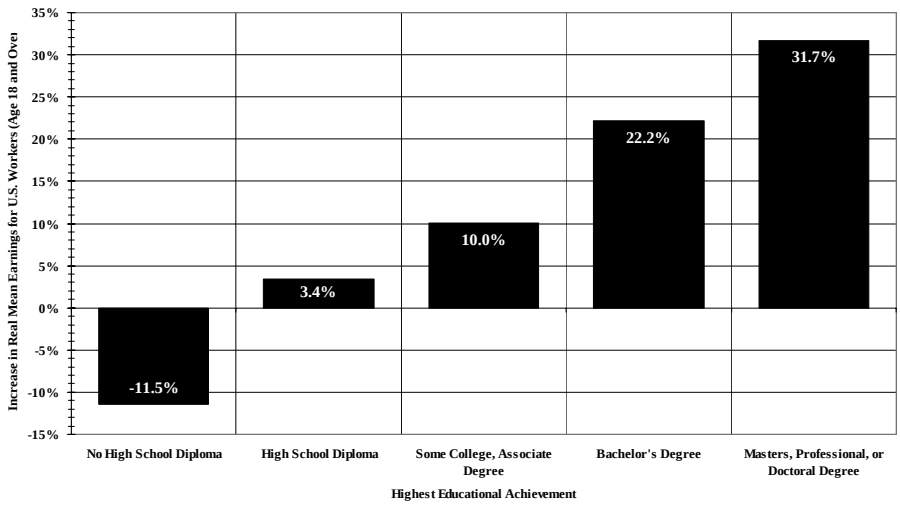
Education premiums. In 1975, U.S. workers with high school diplomas earned a real mean average of $28,471 (all earnings herein are in real 2005 dollars; see Chart 1 for increases in real mean earnings and Chart 2 for education premiums). U.S. workers with bachelor's degrees earned a real mean of $44,767, a premium of 57 percent more than high school graduates, while U.S. workers with masters, professional, or doctoral degrees earned a real mean of $60,714, a premium of 113 percent more than high school graduates.

Over the next thirty years, these education premiums expanded significantly. The real mean earnings of U.S. workers with high school diplomas grew by 3.4 percent to $29,448 in 2005, while the real mean earnings of U.S. workers with bachelor's degrees swelled by 22.2 percent to $54,689 in 2005. Thus, the education premium for college graduates with bachelor's degrees increased to 86 percent.

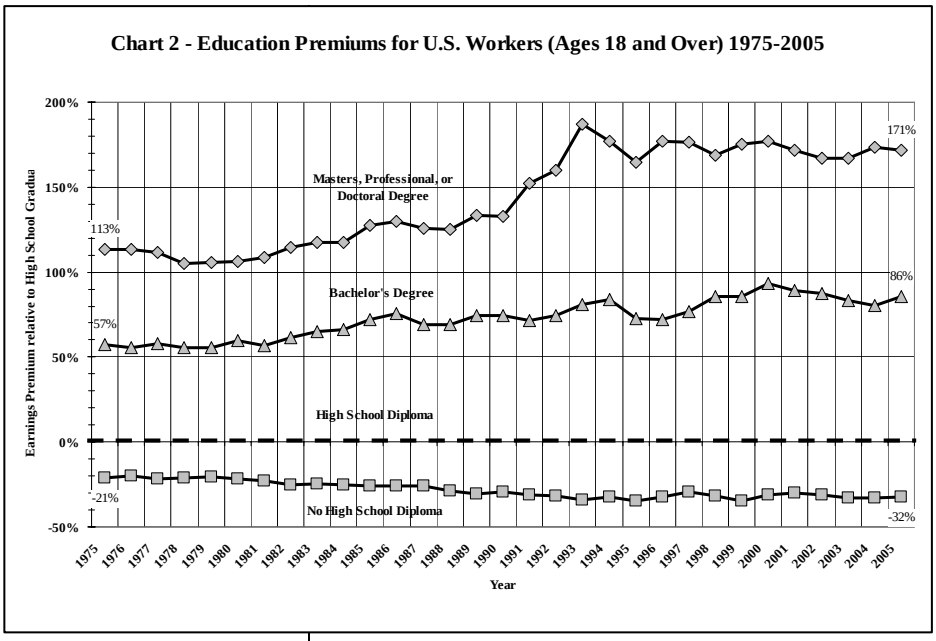
Likewise, the real mean earnings of U.S. workers with masters, professional, or doctoral degrees grew by 31.7 percent to $79,946 in 2005. Thus, the education premium for college graduates with masters, professional, and doctoral degrees expanded to 171 percent.

What caused this expansion of education premiums? During the last three decades, a **skill-biased technological change** (SBTC) altered the demand for different types of labor in the United States. As the real cost of acquiring and using information technology (IT) assets plummeted, U.S. firms substituted computers and computer-driven machinery for workers performing routine tasks. Simultaneously, computerization improved the availability, accuracy and timeliness of information, increasing the marginal productivity of highly skilled, college-educated workers performing cognitive non-routine tasks. Because SBTC concurrently dampened the demand for routine labor and stimulated the demand for cognitive non-routine labor, SBTC increased the real earnings of college graduates relative to less educated workers.

Chart 1 - Change in Real Mean Earnings for U.S. Workers (Age 18 and Over) by Highest Educational Achievement 1975-2005



SBTC explained a majority of the observed changes in the demand for different types of U.S. workers and the real compensation that these workers received over the last three decades. Moreover, SBTC explained a majority of the observed expansion of the earnings differential among U.S. households over the last three decades. Other causes



together explained a minority of the observed changes in labor demand, compensation, and earnings differentials.[1]

Computerization and labor demand. Computers and computer-driven machinery rapidly perform routine tasks that can be expressed logically and codified into a sequence of unambiguous commands to achieve desired results. Thus, firms may substitute IT assets for workers performing routine job tasks (e.g., firms may replace filing clerks with personal computers to maintain their records or welders with welding robots to attach parts on assembly lines).

Computers do not think creatively, handle ambiguity, or solve problems. Cognitive non-routine job tasks (e.g., analyzing problems, creating new products, interacting with suppliers and customers, and managing) require uniquely human input.

Computers dramatically reduce the cost of providing accurate and timely information. By expanding the availability of information, computerization improves decision-making and increases the marginal productivity of highly skilled workers. Thus, IT assets complement cognitive non-routine labor.

Plummeting cost, increasing investment. The real cost of acquiring and using IT assets dropped during the last three decades. From 1975 to 2005, the real cost of acquiring computers and peripherals plummeted by 99.4 percent, while the real cost of acquiring software dropped by 27.5 percent.

The decline in the real cost of acquiring and using IT assets increased computerization. From 1975 to 2005, real private non-residential investment in computers and peripherals rose from less than $500 million to $166 billion, or 1.50 percent of GDP, while real private non-residential investment in software grew from $4 billion to $206 billion, or 1.87 percent of GDP (all investments are in real 2000 dollars; see Chart 3).

Skill-biased technological change. A fall in the real cost of acquiring and using IT assets simultaneously reduces the demand for their substitute, routine labor, and increases the demand for their complement, cognitive non-routine labor. Economists describe this computer-driven shift in the relative demand for different types of labor and the compensation that they receive as a skill-biased technological change. SBTC does not directly affect the demand for manual non-routine labor (e.g., firefighters, servers, and truck drivers).

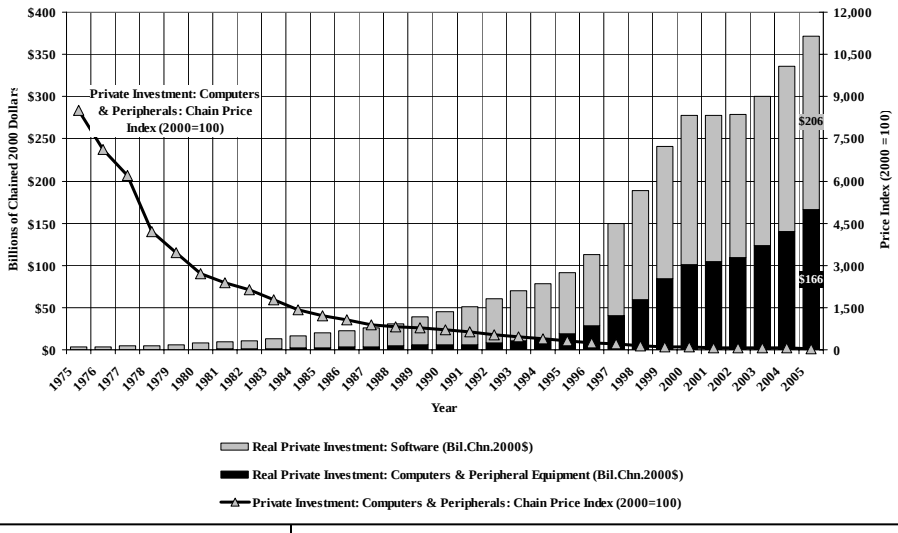
SBTC increased education premiums. Autor, Levy, and Murnane (2003) found strong empirical support for SBTC as the principal cause for shifting labor demand and the resulting increase in the college education premium.[2] The authors employed detailed U.S. Department of Labor data to identify five major categories of job tasks –

(1) cognitive non-routine analytical;
(2) cognitive non-routine communicative, interactive, and managerial;
(3) cognitive routine;
(4) manual routine; and
(5) manual non-routine

– for approximately 450 aggregated occupations in 140 industries spanning the U.S. economy. The authors measured changes in the demand for job tasks from 1960 to 1998.

Throughout the U.S. economy between 1970 and 1998, the demand for routine task inputs (3 & 4) declined, and the demand for cognitive non-routine inputs (1 & 2) increased. The authors found that task shifts occurred primarily within industries rather than between industries. Thus, the observed task shifts were caused by changes in the mix of labor inputs that U.S. firms used in their production processes rather than changes in U.S. consumer demand for goods and services with higher inputs of cognitive non-routine labor.

Chart 3 - Falling Real Costs Drive U.S. Business Investment in Computers, Peripherals, and Software 1975-2005



The authors also tested two formulations of a computerization-task model. One used the annual change in the percentage of an industry's workers using a computer as an independent variable, while the other used an industry's annual investment in computers, peripherals, and software as an independent variable. Either formulation largely explained the observed task shifts within industries, while other independent variables (e.g., aggregate investment) that were statistically insignificant.

The authors found significant task changes within nominally unchanged occupations. For example, secretaries typically perform more analytical, communicative, interactive, and managerial functions and fewer routine functions today than secretaries did a generation ago. The computerization-task model explained these task changes within occupations.

Finally, the authors translated the observed task changes into the demand for college-educated and non-college-educated labor. Since 1980, the "model can explain a large fraction – 60 to 90 percent – of the estimated increase in relative demand for college employment. Notably, almost 40 percent of the computer contribution to rising educational demand in the last two decades is due to shifts in task composition within nominally unchanging occupations."[3]

SBTC expanded income inequality. Autor, Katz, and Kearney (2006a, and 2006b) found strong empirical support that SBTC-induced changes in real compensation accounted for a majority of the observed changes in inequality in U.S. income distribution during the last three decades.[4]

High school graduates that perform routine job tasks are clustered in the middle of the U.S. income distribution,[5] while college graduates that perform cognitive non-routine job tasks are clustered in the top two quintiles.[6] By widening education premiums, SBTC has caused a secular expansion of inequality in the upper half of the U.S. income distribution over the last three decades. For example, the 80th percentile to median household income ratio increased from 1.78 in 1980 to 1.98 in 2004, while the 95th percentile to median household income ratio grew from 2.86 in 1980 to 3.54 in 2004.

Worldwide phenomenon. Expanding education premiums and growing income inequality are not limited to the United States. In its most recent *World Economic Outlook*, the International Monetary Fund reported, "The income share of labor in skilled sectors [in developed economies] … has been on the rise, especially in Anglo-Saxon countries."[7]

Moreover, developing economies have experienced explosive growth in the real compensation paid to highly skilled, college-educated workers relative to other workers in their

economies. Thus, education premiums have expanded more rapidly in developing economies such as China and India than in developed economies such as the United States.[8] While SBTC did contribute to these changes, other factors such as domestic economic reforms and globalization are likely to have played greater roles in developing economies than in the United States.

Conclusion. Skill-biased technological change is the major cause for higher education premiums and the resulting increase in income inequality among U.S. households since the 1970s. This secular trend has continued through multiple U.S. business cycles, different presidential administrations, and a variety of federal policies toward taxes, spending, and regulation. This trend is occurring simultaneously in many economies, both developed and developing, around the world.

Since few would forgo the life-improving, productivity-enhancing, and growth-generating benefits of IT assets merely to reduce income inequality, policymakers must seek other ways to increase economic opportunities, especially for Americans in the lower half of the income distribution. The most promising approach is to improve the quality of primary and secondary education so that all Americans may pursue college educations and consequently earn more over their working lives. In addition, it could be made easier for older workers to obtain a college education so that they may enhance their marketable skills and increase their earnings.

[1] The **progressive liberalization of international trade and investment** tends to increase the compensation of highly skilled workers relative to less skilled workers in both developed and developing economies. For example, see Robert C. Feenstra and Gordon H. Hanson, "Foreign Investment, Outsourcing, and Relative Wages," National Bureau of Economic Research Working Paper No. 5121 (May 1995); Robert C. Feenstra and Gordon H. Hanson, "Global Production Sharing and Rising Inequality: A Survey of Trade and Wages," in Kwan Choi and James Harrigan, eds., *Handbook of International Trade*, Basil Blackwell (forthcoming); and Pinelopi Koujianou Goldberg and Nina Pavcnik, "Distributional Effects of Globalization in Developing Economies," National Bureau of Economic Research Working Paper 12885 (February 2007**). Large scale immigration of low-skill workers** may have depressed real wage growth in the lower half of the income distribution. See: George J. Borjas, "Native Internal Migration and the Labor Market: Impact of Immigration," (May 2004). Finally, **statistical anomalies** such as the steady **decline in the size of the average household** can disguise real income growth. The average household size declined from 3.33 persons in 1967 to 2.62 persons in 2005. From 1967 to 2005, real mean household income grew by 60.1 percent to $63,344, while real mean size-adjusted household income expanded by 104.0 percent to $80,715.

[2] David H. Autor, Frank Levy, and Richard J. Murnane, "The Skill Content of Recent Technological Change: An Empirical Exploration," *Quarterly Journal of Economics*, 118(4), November 2003.

[3] Computerization contributed to a rapid increase in CEO compensation by reducing the importance of firm-specific knowledge and increasing the importance of general management skills. Successful managers seeking a CEO position are less limited by firm-specific knowledge to their current firm. As firm-specific knowledge has become less important, firms can easily hire a successful CEO away from another firm in a different industry. This expanded competition among firms for talented CEOs has increased CEO compensation. Kevin J. Murphy and Jan Zabojnik, "CEO Pay and Appointments: A Market-Based Explanation for Recent Trends, *American Economic Review* (May 2004), 192-196.

[4] David H. Autor, Lawrence F. Katz, and Melissa S. Kearney, "The Polarization of the U.S. Labor Market," National Bureau of Economic Research Working Paper 11986, January 2006; and David H. Autor, Lawrence F. Katz, and Melissa S. Kearney, "The Polarization of the U.S. Labor Market," *American Economic Review*, May 2006, 189-194.

[5] The median income for households headed by a high school graduate was $38,191 in 2005. This was in the third quintile.

[6] The median income for households headed by a college graduate with a bachelor's degree was $72,424 in 2005. This was in the fourth quintile. The median income for households headed by a college graduate with an advanced or professional degree was $100,000 in 2005. This was in the top quintile.

[7] International Monetary Fund, "The Globalization of Labor" in *World Economic Outlook*, Washington, D.C., April 2007.

[8] Goldberg and Pavcnik (February 2007).