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Education, Skills, and Technical Change

Implications for Future US GDP Growth

Introduction: Education, Skills, and Technica...

Edited by
Charles R. Hulten
and Valerie A. Ramey

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Prefatory Note

This volume contains revised versions of the papers presented at the Conference on Research in Income and Wealth titled "Education, Skills, and Technical Change: Implications for Future U.S. GDP Growth," held in Bethesda, Maryland, on October 16–17, 2015.

We gratefully acknowledge the financial support for this conference provided by the Bureau of Economic Analysis. Support for the general activities of the Conference on Research in Income and Wealth is provided by the following agencies: Bureau of Economic Analysis, Bureau of Labor Statistics, Bureau of the Census, Board of Governors of the Federal Reserve System, Statistics of Income/Internal Revenue Service, and Statistics Canada.

We thank Charles R. Hulten and Valerie A. Ramey, who served as conference organizers and as editors of the volume.

Executive Committee, December 2016

Introduction

Charles R. Hulten and Valerie A. Ramey

Overview

The growth in future living standards in the United States will likely depend to a significant degree on the continued evolution in the "knowledge" segments of the economy. These are the high-value-added sectors where product and organizational innovation generates high levels of productivity and creates new goods and markets. They are also the sectors that are the least vulnerable to global competition from low-wage manufacturing economies. Technology has already transformed many sectors with innovations like mobile communication devices, e-commerce, global supply-chain management, customization of manufacturing products, and GPS-based transportation management, and there is likely more to come with big data, the evolution of automated "workerless" factories and driverless vehicles, and developments in the areas of artificial intelligence, 3-D printing, nanotechnology, and genomics. Evidence suggests that such innovations often require a parallel transformation in worker skills in order to implement and operate the new technology and business models. A workforce that cannot play this role may limit the rate of innovation and may slow the growth in living standards.

A century ago the United States became a world leader in the expansion of secondary and tertiary education, a development that helped propel US

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productivity growth for decades, a thesis advanced in the 2010 study by Goldin and Katz. However, recent macroeconomic evidence suggests that the contribution of human capital accumulation to US growth has slowed in recent decades and the slowdown may last into the future. Moreover, the long-standing problem of the *quality* of the US primary and secondary education system has continued to be a source of concern, despite decades of efforts to improve the US education system. According to the Organisation for Economic Co-operation and Development (OECD)'s 2015 PISA survey of fifteen-year-olds, the US math performance was significantly below the mean OECD performance.[1]

The 2013 Programme of International Assessment of Adult Competencies (PIAAC) tells a similar story in its survey of the skill distribution of adults age sixteen to sixty-five in twenty-four countries. The literacy results for the US population are slightly below those of the OECD as a whole, but are considerably below the OECD in numeracy. Indeed, only a third of US respondents scored at the upper levels in math compared to around a half of OECD respondents.[2] This is all too consistent with the results of the recent "Nation's Report Card" (NAEP 2015) from the US Department of Education. This survey of American 12th graders found that only one in four were proficient or higher in mathematics and only two in five in reading ability. The study also found that the literacy and numeracy skills of 12th graders have been stagnant in recent years.

The implications of the trend in human capital formation and its interaction with technology for the future of US growth are the subject of the Conference on Research in Income and Wealth conference "Education, Skills, and Technical Change: Implications for Future US GDP Growth," held in Bethesda, Maryland, October 16–17, 2015. This conference volume contains twelve chapters exploring various aspects of this question, with discussant comments for many of the chapters. The contributors span an unusually broad range of expertise, including experts on aggregate productivity growth, cross-country comparisons of test scores and skill levels, the skill and task requirements of jobs, broader concepts of labor skills such as "noncognitive skills," alternatives to traditional education such as on-the-job training and online education, the role of immigration in skill supply, and the structure of the higher education sector.

We begin this introduction with some general observations about the way human capital affects economic growth and review the channels through which the skills and education of the labor force impact gross domestic product (GDP) growth. We then offer our own summary assessments of many of the salient issues before providing a brief summary of the chapters themselves.

1. OECD (2016, *Snapshot Table*, 5).
2. OECD (2013, tables A2.1 and A2.5).

Human Capital's Contribution to GDP Growth

Virtually every aspect of economic activity involves human agency of some sort, whether it involves decisions about business models and management procedures, innovation, capital investment, and, perhaps most important of all, the skills and motivation that workers bring to their jobs. The quantity and quality of this agency matter, and this is where education comes into play. While formal education is not the only way that human capital is built, it provides the foundational infrastructure of literacy, numeracy, and general information that informs the functioning of an advanced society, including its economy. It also provides important vocational and professional skills.

How important is education and the knowledge it imparts compared to other factors that affect economic activity? Economic historians and economists specializing in the field of education generally see educational attainment and human capital development as critical factors in the process of economic growth. Hanushek and Woessmann (2015, 1) start their book, *The Knowledge Capital of Nations*, with the statement that "knowledge is the key to economic development. Nations that ignore this fact suffer, while those that recognize it flourish." Moreover, it is not just the average level of education that matters. Economic historian Joel Mokyr argued in 2005 that it was those in the upper tail of the knowledge distribution that were responsible for much of the technological development that drove the Industrial Revolution. David Landes (1998, 276), in his appraisal of the factors that determine the *Wealth and Poverty of Nations*, sums up with the following observation: "Institutions and culture first; money next; but from the beginning and increasingly, the payoff was to knowledge."

The importance of acquiring knowledge is well understood by the population at large, if historical statistics on educational attainment are any indication. The proportion of persons older than age twenty-five with college degrees increased from around 5 percent in 1950 to 30 percent in 2010, and two-thirds of high school graduates went on to some form of tertiary education in 2012, up from 50 percent in 1975.[3] This increase was driven, in part, by the growing wage premium for a college education documented in the work of Goldin and Katz (2010), and by Valetta writing in chapter 9 of this volume. The dramatic increase in schooling was matched by a large increase in the national commitment to education. Annual real expenditures per student rose over the period 1960 to 2011, from around $3,000 to $11,000, and when private spending is added to public outlays, the combined direct investment rate in education in the United States in 2011 was nearly 7 percent of GDP.[4]

3. US Census Bureau (2015).
4. These estimates are from table 236.55 of the *2013 Digest of Educational Statistics* (NCES 2013).

This is an impressive record. There is, however, another important question: Does more education necessarily lead to more economic growth? Are past results indicative of future returns? On the one hand, the demand for college graduates may have decreased, and, as noted, the macroeconomic contribution of education to aggregate output growth seems also to have slowed. On the other hand, the underlying factors that have propelled the demand for higher education and more complex skills—skill-biased and labor-saving technical change and the globalization of the world economy—proceed apace (for now), and the demand for college-educated workers is increasingly a demand for postgraduate and professional education. These are issues that high-income societies like the United States face today in their efforts to sustain the economic growth needed to improve living standards for a broad range of the population, and not just for those with college degrees.

The Channels through Which Human Capital Affects GDP Growth

Economic growth is a complex process influenced by many factors, and education is a multifaceted process that affects growth through multiple channels. As a backdrop for the material presented in the various chapters of this volume, we identify and comment on five of these channels:

1. Worker Productivity. Education operates directly by raising the marginal productivity of workers. The Mincer wage equation is a staple of labor economics, linking education, cognitive skills, and other individual characteristics to wage rates, which are in turn linked to the value of the marginal product of labor. When these individual productivity effects are aggregated, they constitute a potentially important source of growth in real GDP. The size of and relative importance of this effect can be estimated using the growth-accounting method pioneered by Jorgenson and Griliches (1967) in their pathbreaking paper and employed by the Bureau of Labor Statistics (BLS 1983) in their Multifactor Productivity program. The chapters by Jorgenson, Ho, and Samuels, and by Bosler, Daly, Fernald, and Hobijn in this volume provide estimates based on this method, which suggest that education may make a relatively smaller contribution to growth than in the past.

2. Skill-Biased Technical Change. Changes in the nature of technology in recent decades have shifted the demand for labor skills in favor of those involving nonroutine cognitive activities. Education is one factor that accommodates this skill-biased technical change, which can affect output growth above and beyond the direct marginal product effect, as set out in the important 2011 and 2012 contributions by Acemoglu and Autor. Moreover, shifts in the microstructure of production activities have tended to involve workers with advanced skills that are strong complements with the more sophisticated types of capital and technology, and are thus necessary inputs whose absence can limit growth (Hulten, chapter 3, this volume). This demand for these "necessary" workers is one factor driving the growth of the college wage premium.

3. Innovation. The education sector is a prime source of the new ideas and perspectives that lead to technical innovation, and education is important for the adoption and diffusion of technology, as Nelson and Phelps (1966) emphasize in their contribution. Other research suggests that technologies diffuse more quickly when basic literacy and numeracy are more widespread.[5] In other words, innovation is an endogenous process that depends in part on education, both for its development and diffusion.

4. Knowledge Spillovers. The development and transmission of knowledge involves spillover externalities in which the social return to investments in both education and research and development (R&D) exceed the private return. In the case of education, the spillover occurs because educated people interact in ways that are not mediated by a labor market return (Lucas 1988). With R&D, the knowledge spillover arises from the inability of innovators to completely protect their property rights against diffusion to other users (Romer 1986, 1990).

5. Social Capital. Education is part of the foundational infrastructure that sustains social, political, and economic institutions. This mechanism is perhaps not so much a specific channel as it is an infrastructural investment in building or maintaining social capital. It involves the Landes emphasis on institutions and culture as sources of national prosperity, but the following quote, attributed to Thomas Jefferson, perhaps says it best: "If the children are untaught, their ignorance and vices will in future life cost us much dearer in their consequences than it would have done in their correction by a good education."

The chapters in the volume are focused largely on various aspects of the first two channels. This focus should be kept in mind when assessing the impact and value of education, since a great deal of education's overall value is created through the other channels.

The Supply and Demand for Skills and Education: An Overview

Individual chapters are summarized briefly in the next section, but, before going there, we offer a summary assessment of what we see as the main points. They reflect our reading of the chapters, as well as our own research and understanding of the issues, and they should not necessarily be attributed to any individual author or discussant whose work appears in the volume.

1. A strong education system is essential for the proper functioning of modern economies, and is the hallmark of an advanced society. Evidence suggests that those societies with the highest income per capita are also

5. See, for example, Benhabib and Spiegel (2005).

those with the greatest educational attainment. Education played a particularly key role in the transition over the last half century to a globalized "knowledge economy" by helping provide the requisite nonroutine cognitive and noncognitive skills. Without the appropriate supply response to the changing demand for skills, it is hard to see how this revolution could have occurred in its current form.

2. More is involved in skill development and learning than formal education alone. Home environment is an important determinant of skill formation, with the cognitive and noncognitive skills developed in early childhood playing a fundamental role in a child's ability to learn. The socioeconomic status of the family also matters (see, e.g., Ramey and Ramey 2010), as do idiosyncratic factors like ability. Moreover, skill development does not stop at graduation. Research at the BLS reported in the Gittleman, Monaco, and Nestoriak chapter in this volume has found that the formal school preparation placed third behind training and job experience as a source of skill development. On the other hand, education does provide the general skills of literacy and numeracy needed for the further development of many task-related skills, and is the main *systematic* way that children are prepared for adult life and the world of work. It also provides vocational training and preparation for various professions, and educational attainment has been found to be positively correlated with employment in jobs requiring more complex cognitive and noncognitive skills.

3. Much of the recent focus on the demand side of skill development has been on the higher-order cognitive and noncognitive skills needed for the growing complexities of the technology revolution. This is appropriate, given that these skills are an important enabler of that revolution and the income growth it has created. However, it is also true that only a fraction of all jobs involve complex tasks (around 15 percent, according to the BLS study in this volume), and only a quarter of all jobs require a college degree. Any discussion of the demand for skills must acknowledge the fact that the education system needs to prepare students for a broad range of skills and vocations, not just those at the top ends of the skill and educational attainment scales. This is all the more important because the requirements of many "routine" skills have shifted as a result of sectoral changes in the structure of the economy and the growing presence of information technology.

4. Much of the initial focus on the demand for skills was on higher-order cognitive skills, but the importance of noncognitive "soft" skills has been increasingly appreciated. These soft-skill traits include self-discipline, conscientiousness, and the ability to get along with others. These traits are hard to pin down analytically, but studies suggest that they are rewarded in the labor market (see the study by Lundberg and the discussion by Deming in this volume). They are important for the full spectrum of jobs, but are particularly important for jobs that involve less direct supervision.

5. Increased college-participation rates are not a panacea for address-

ing income equity and prompting more rapid economic growth. Not only are there limits on the demand for the skills of college-educated workers, there are supply-side issues as well. Research by James Heckman and colleagues has emphasized the importance of "college readiness" and the limits it imposes on individual higher education outcomes.[6] While the average college wage premium is still large, not everyone receives this premium. A study by Abel and Deitz (2014) finds that the lowest quartile incomes of college graduates only marginally outperformed the median incomes of high school graduates.

6. At the other end of the wage premium spectrum, the United States stands out in the PIAAC international comparison in its propensity to reward those with the highest skills (Broecke, Quintini, and Vandeweyer, chapter 7, this volume). This is significant in view of the Mokyr hypothesis that those in the upper-tail knowledge of the distribution play a key role in technological development. They are prominent in the research labs of universities and companies, the C suites of corporations, and software development divisions of technology companies.

7. Education is a process that unfolds over time for any given individual and is fraught with uncertainty and institutional problems and rigidities. Thus, the adjustment of the supply of new graduates to a change in demand for a skill or occupation cannot occur immediately, leading to periods in which demand growth may outstrip supply. Goldin and Katz argue that this phenomenon occurred as the information revolution increased the demand for complex skills and higher education, and a lagging supply response led to a college wage premium as the natural market outcome. Some have interpreted this as a worrisome "skills gap," but standard economic logic sees it as a period of labor market adjustment. Indeed, recent evidence suggests that the uptake of college graduates may be slowing, along with the wage premium for college (see Beaudry, Green, and Sand [2016] and chapter 9 in this volume by Valletta, as well as the comment on chapter 9 by Autor).

8. Immigration is an important source of the supply of highly skilled and educated workers, and is particularly important in the science, technology, engineering, and mathematics (STEM) areas. Hanson and Slaughter, writing in chapter 12 of this volume, report that the foreign-born share of STEM employment in 2013 was approximately 20 percent among those with bachelor's degrees, 40 percent among those with master's degrees, and 55 percent among PhDs. Expressed in terms of hours among prime-age workers (those thirty to forty-five years of age) with an advanced degree, the foreign born accounted for nearly one-half of total hours worked in STEM occupations in 2013, up from around one-quarter in the 1990s and one-fifth in the 1980s. These estimates refer to STEM workers. Immigration has also

6. See Heckman, Stixrud, and Urzua (2006) and Heckman, Humphries, and Veramendi (2016).

been an important source of entrepreneurship, according to the study by Kerr and Kerr (2017).

9. The quality of education matters as well as the quantity. In this regard, the success of the US education system in preparing students with the skills needed for the economy of the twenty-first century gets a mixed report card. According to Current Population Survey (CPS) data, most students today finish high school (some 90 percent), and two-thirds go on to some form of tertiary education.[7] Not all succeed in obtaining a four-year college degree, as only around one-third of the population end up with a four-year college degree or more (though Abel and Deitz, in chapter 4 of this volume, show that many of those who do not find jobs requiring a college degree end up in fairly well-compensated employment). The quality of US higher education is very high in international comparisons, but there are still problems facing college students: rising tuition (see chapter 10 in this volume by Gordon and Hedlund), the growing burden of student debt, and retention and lengthy time-to-graduation are issues. The college "industry" is also undergoing changes in the technology of teaching made possible by the digital revolution, not the least of which is the rise of online education (Hoxby, chapter 11, this volume). On the other hand, the educational outcomes at the K–12 level revealed by the National Assessment of Educational Progress (NAEP 2015) and by international comparisons point to deeper and more persistent problems.[8] However, the K–12 results cannot be attributed to the quality of schooling alone. Research suggests that the cognitive and noncognitive skills developed by age three have fundamental effects on the ability to learn. Thus, K–12 schools have little control over a key input into their production functions.

10. Combined with those students who do not finish high school, the test-score results suggest that a substantial portion of US youth is not being prepared for the needs of the knowledge economy and the affluence it conveys, or for the remaining medium-skill jobs that in the past have provided middle-class affluence. While higher education, with its large wage premium, is a pathway to higher incomes for some, many others are left behind. Finding an answer to this equity versus growth conundrum is one of the great educational and economic challenges of the years ahead.

We emphasize, again, that these points reflect our own views and understanding of the subjects covered and should not be attributed to any individual author or discussant.

7. US Census Bureau (2015).

8. One NAEP result is particularly noteworthy in this regard. More than a third of the 12th grade students surveyed scored in the below basic category in reading and almost 40 percent in mathematics. These deficits have persisted over time and they do not bode well for future employment in an increasingly technological world economy.

Summary of the Chapters in the Volume

The chapters in this volume touch on one or more of the issues raised in the preceding section. We turn now to a brief summary of these chapters and discuss how they help address those issues.

The Macroeconomic Link between Education and Real GDP Growth

The volume begins with three chapters that use a growth-accounting model to measure the contribution of labor quality to GDP growth. These are the chapters by Jorgenson, Ho, and Samuels; Bosler, Daly, Fernald, and Hobijn; and Hulten. The first two chapters are followed by a general discussion of the issues by Douglas W. Elmendorf, whose perspective as former head of the Congressional Budget Office (CBO) illustrates the policy relevance of the questions being asked.

The first two chapters use the Jorgenson and Griliches (1967) extension of the Solow (1957) growth-accounting framework as a starting point. The great advantage of the Solow framework is its ability to sort out the contributions of the three general factors responsible for growth: labor, capital, and technology. Jorgenson and Griliches took this a step further by adding the labor "quality" to this list, defining it as the shift in the composition of labor force characteristics (including education) to those with higher or lower marginal products. This framework disaggregates labor into its various characteristics and assumes that wage rates accurately reflect the corresponding marginal products. It then resolves the results into indexes of the quantity of labor input and its composition/quality.

The chapter "Educational Attainment and the Revival of US Economic Growth" by Jorgenson, Ho, and Samuels analyzes the recent past and projected future of labor-quality growth and overall GDP growth using a newly constructed KLEMS (capital, labor, energy, materials, and purchased services) sixty-five-industry data set from 1947 through 2014. Despite an overall slowdown in educational attainment of the population, Jorgenson et al.'s labor-quality series shows a continuing significant contribution of educational attainment to labor quality from 2007 through 2014. The source of this discrepancy is the decline in employment participation of the less educated, so the average educational attainment of the employed continued to rise. Looking forward, Jorgenson et al. project that labor-quality growth will contribute essentially nothing to growth from 2014 to 2024 if the recent decline in the employment participation rate of the less educated is reversed.

An empirical challenge facing users of the Jorgenson-Griliches framework is the construction of the labor-quality index, since it is not directly observable. The chapter "The Outlook for US Labor-Quality Growth" by Bosler, Daly, Fernald, and Hobijn begins by addressing this problem. The standard way to estimate labor quality is to invoke the assumption of competitive factor markets and use wages as a measure of marginal product. One approach used in the labor economics literature regresses the wages of individual workers on their observable characteristics such as education level, gender, experience, and so forth, and then uses the estimated coefficients to derive weights in order to construct a labor-quality index. As Bosler et al. explain, researchers face a trade-off: adding more detailed characteristics explains more of the variation of wages across workers, but at the same time reduces the precision of the marginal product estimates because the number of workers in each cell falls. Bosler et al. explicitly show the trade-off across almost 2,000 specifications that vary in the number of worker characteristics included, how finely these characteristics are disaggregated, and the functional form. The authors then construct an index of labor quality for their preferred specification, as well as several of the leading alternatives.

Bosler et al.'s analysis confirms Jorgenson et al.'s findings that the much-discussed decline in the employment-population ratios of the less educated has contributed to labor-quality growth through a composition effect on the employed. These same employment-population movements create uncertainty about the future growth rate of labor quality, however. If the employment of the less educated recovers, the labor force will grow faster than otherwise expected, but labor-quality growth will be slower. Bosler et al. also offer several projections of future labor-quality growth. Their preferred projections are for labor quality to grow relatively slowly, from 0.1 to 0.25 percent per year, for the longer run reaching 2025. If these projections are borne out, they mean that labor-quality growth will be a less important part of GDP growth in the future than it has been in the past. In other words, the slowdown in educational attainment in the United States will finally start showing up in aggregate labor-quality growth.

The chapter by Hulten, "The Importance of Education and Skill Development for Economic Growth in the Information Era," is the third of the chapters in the volume that deal with growth accounting. Where the methodology of Jorgenson et al. essentially follows the approach of Jorgenson and Griliches (1967), and Bosler et al. explore alternative ways of measuring the labor-composition term of that model, the Hulten chapter proposes an alternative way of looking at the technology that underpins the growth-accounting framework. This alternative approach is motivated, in part, by the view that education plays a more fundamental role in enabling economic activity than is implied by the labor-composition effect, and that this might help explain the relatively small *measured* role in output growth over the course of the information revolution. Hulten builds on the Acemoglu and Autor (2012) insights about task-skill links, but develops them in the context of a disaggregated activity-analysis technology. In this framework, the business model of a firm specifies the kinds of goods to be produced and how they are marketed, and the execution of these decisions is broken down into various activities within the firm. In the strict version of this model, each activity uses inputs in a fixed proportion, meaning that each type of skilled labor and capital is a necessary input. This provides a mechanism through which the more complex forms of capital, both tangible and intangible, are linked to the higher-order labor skills needed to operate that capital. This "necessary input" model contrasts with the conventional aggregate production function approach to growth accounting, which groups input into capital and labor aggregates and assumes a high degree of substitutability between them.

One goal is to examine the implications of this "necessary input" feature of the activity-analysis model for conventional aggregate sources-of-growth estimates. This leads to the salient result that the empirical sources-of-growth results reported by BLS *could equally have been generated by the activity-analysis model*. This enables these results to be interpreted in a very different way than under the standard Solow aggregate production function interpretation, one that assigns a greater importance to labor skills and education.

Jobs and Skills Requirements

Preparing students for jobs is not just a matter of inducing them to attend school for a certain number of years, since there is no guarantee that the skills students learn in school will match those demanded by employers. The two chapters in this section shed light on the issue of this match and the demand for skills. The first chapter studies the outcomes of recent college graduates, and the second surveys the skill requirements of jobs.

"Underemployment in the Early Careers of College Graduates following the Great Recession" by Abel and Deitz studies an issue that has received much attention from the press: Are recent college graduates finding jobs that match their education level? Following the Great Recession, newspapers published a number of stories about recent college graduates who ended up working as baristas in coffee shops. Abel and Deitz study the validity of this picture by constructing and analyzing detailed data on the unemployment and underemployment experiences for recent graduates. Unemployment rates by education are readily available, but *underemployment* rates are not part of the standard government statistics. The authors construct new series on underemployment rates of recent graduates using information from the Department of Labor's O*NET database, which contains information on the characteristics of hundreds of occupations based on interviews of incumbent workers and occupational specialists. They discover that underemployment of this group is not a new phenomenon. In fact, their series shows a rough V-shape since 1990. The current level of 45 percent underemployment of recent college graduates still lies below the level that prevailed in the first half of the 1990s.

A question that arises is, What sort of jobs do the underemployed recent college graduates take? The Abel-Deitz results show that most underemployed recent graduates did not end up working in low-paid service jobs (e.g., baristas). Rather, nearly half ended up in relatively high-paying occupations, such as information processing and office and administrative support. Only 9 percent of all recent college graduates began their careers in low-paying service jobs. Thus, even if a college degree did not guarantee an initial placement in an occupation requiring a college degree, it did give individuals a competitive advantage in the occupations that did not require a college degree.

"The Requirements of Jobs: Evidence from a Nationally Representative Survey" by Gittleman, Monaco, and Nestoriak describes a new survey conducted by the Bureau of Labor Statistics (BLS) and reports findings from the preproduction test survey. The BLS launched the Occupational Requirements Survey (ORS) in collaboration with the Social Security Administration as a data source in disability adjudication. The rich information from the survey can be used to answer a number of other economic questions, including the demand for and returns to education and skills in occupations.

Gittleman et al. use these data to study the requirements of jobs. An important finding is that fewer than 25 percent of jobs require a college degree or higher degree, somewhat less than reported in the O*NET data (around 27 percent). This relatively small fraction stands in contrast to the common assertion that earning a college degree has become de rigueur for employment in the twenty-first-century US economy. The bottom line is that three-quarters of all current jobs do not *require* a four-year college degree.

Additional results suggest that there are many jobs that do not require complex tasks, or that allow only loose control. Any policy aimed at significantly increasing college enrollments should take note of these findings. However, it is also important to note that these results do not diminish the importance of a higher education for those jobs for which it is needed. Moreover, Gittleman et al.'s analysis of average wages by job characteristic reflect large premiums for education. Thus, the more nuanced interpretation of the Gittleman et al. results is that while there are many jobs available for individuals with low education and skill levels, those jobs pay much less than those with higher education and skill levels.[9]

Skills, Inequality, and Polarization

The chapters in the last sections go beyond the standard practice of equating labor quality or skill with years of education. The chapters in this section consider additional dimensions. One chapter branches out to consider

9. We emphasize that these wage outcomes should not be interpreted as a type of "demand" for skills indicator irrespective of supply. The creation of a job or occupation is the outcome of the interaction of particular demands in the face of a supply of skills in an economy. Thus, firms facing a badly educated workforce would be expected to adapt by fashioning their job requirements around the supply of skills, and using technology in ways that overcome gaps in skill supply.

noncognitive skills, and the other three consider the distribution of skills rather than just the average.

"Noncognitive Skills as Human Capital" by Lundberg discusses both what we know about the importance of noncognitive skills in individuals' outcomes and the measurement challenges for quantifying these types of skills. The standard measures of human capital include years of education, cognitive test scores, and/or IQ-related measures (such as the Armed Forces Qualifying Test [AFQT]). A literature that emerged in the first decade of the twenty-first century showed that it might be valuable for economists to broaden their concept of human capital to include "noncognitive skills" in the form of personality traits. As Lundberg points out, however, measures of noncognitive skills are not always reliable in all applications. She cites a lack of consensus on what noncognitive skills really are, as well as a lack of a consistent set of metrics across studies. Part of her chapter points out the current gaps and what would be needed to consider the role of noncognitive skills in economic growth. Among the challenges are establishing a *causal* channel based on estimated relationships in which unobserved factors may be playing a role and evidence on the heterogeneity of returns to noncognitive skills across different environments.

To illustrate the issues involved, Lundberg uses the NLSY97 and the Add Health surveys to estimate the relationships between noncognitive skills and outcomes. A number of interesting results emerge that show the difficulty of interpreting results. First, the correlation between various measures of noncognitive skills is surprisingly low. Second, the important and statistically significant effects of many of the noncognitive skill measures on wages and employment often disappear once educational attainment is included in the regressions. These results suggest that a key channel of influence of noncognitive skills on labor market outcomes might be through educational attainment and not through the direct channel of on-the-job performance. Third, the importance of certain measures of noncognitive skills in predicting outcomes such as crime are not necessarily robust to adding other measures of noncognitive skills.

Overall, Lundberg's chapter highlights the fact that noncognitive skills are potentially very important for thinking about human capital and productivity more broadly. There are still many problems to be solved in making this analysis more concrete and filling in the causal steps. Lundberg's chapter is very useful for pointing out the key gaps that need to be filled in the literature.

The next chapter in the section, by Broecke, Quintini, and Vandeweyer, uses data from the latest survey of the Programme for the International Assessment of Adult Competencies (PIAAC) to determine how much of the differences in wage inequality across countries can be explained by differences in the endowments of and return to skills across countries. Their chapter contributes to a debate about whether a difference in skill distributions or institutions can best explain differences in inequality across countries.

Broecke et al. begin by comparing the distribution of skills—they concentrate on numeracy in particular—and the distribution of wages within a number of countries. They find that the United States has one of the lowest average levels of adult skills, but also one of the highest dispersions of skills. Moreover, the United States has the highest returns to skills, is among the countries with the highest average levels of wages, and is near the top in wage inequality.

Broecke et al. conduct accounting exercises in order to analyze the extent to which the endowment of skills and the return to skills can explain wage inequality differences across countries. They find that differences in the *returns to skills* in the United States are much more important than differences in the *endowment of skills* in accounting for the inequality of wages in the United States relative to other countries. Overall, this chapter shows how concrete measures of skills and their returns can help explain differences in inequality across countries. An additional outcome of their study is the clear demonstration that the average skill level of American adults lags behind many other OECD countries. It is also apparent, however, that the demand for skills in the United States remains high, as evidenced by the high-skill premium.

Erik Hanushek's chapter, "Education and the Growth-Equity Trade-Off," considers a number of important issues concerning the link between cognitive skills, growth, and inequality. He first considers the role of human capital in growth models. As he points out, in neoclassical models, a rise in human capital will raise the *level* of output, but not the steady-state growth rate of output. In contrast, in endogenous growth models, a rise in human capital can potentially raise the steady-state growth rate of output. The second point he makes is how years of educational attainment is a poor measure of human capital. Hanushek notes that the quality of educational systems differs dramatically across countries, and even possibly across time. Illustrating the findings from his earlier work with coauthors, he shows that in a cross-section regression of long-run growth rates, average years of education performs poorly relative to his preferred measures that use the results of international assessments of test scores and similar metrics.

Robert Valletta's chapter, "Recent Flattening in the Higher Education Wage Premium: Polarization, Skill Downgrading, or Both?," focuses on trends in wage premiums. He particularly studies possible sources for the documented flattening in the returns to education. Since 1980, educational wage premiums have increased, but they have done so at a decreasing rate. The premium for college only (i.e., four-year college degree, but no graduate school) over high school rose the fastest in the 1980s, slightly less fast in the 1990s, and then stalled since 2000. The premium for graduate degrees rose more robustly during most decades, but appears to have stalled since 2010.

Valletta then considers the extent to which two possible hypotheses can explain these trends. First is the job polarization hypothesis (e.g., Autor, Katz, and Kearney 2008; Acemoglu and Autor 2011), which argues that skill-biased technological change has reduced the demand for routine jobs that can be computerized. In this hypothesis, the middle-educated (e.g., some college or college only) lose their jobs and are forced to move down to nonroutine, noncognitive jobs that pay much less. A second hypothesis, which expands on the polarization hypothesis, is "skill downgrading" by Beaudry, Green, and Sand (2016). They argue that the rise in educational premiums was in part a transitional effect of moving to a higher level of intangible organizational capital. Demand for cognitive skills was high when investment in information technology (IT) was high during the transition to the new steady state, but once the new state was reached, there was less demand for those types of cognitive skills. To shed some light on the forces at play, Valletta analyzes changes in premiums within and between broad occupation categories as well as shares of workers by education in those groups. Valletta interprets his results as suggesting rising competition among educated workers for high-paying jobs that are becoming more scarce. He argues that even if the social return to higher education might be slowing down, the private returns are still large because it enables workers to compete for the best-paying jobs.

The Supply of Skills

Our opening comments describe some of the frictions arising in the formal education sector in the United States that tend to slow the supply response of skills to shifts in demand. In the same vein, this section begins with a chapter that examines the sources of the rise in college tuition in the United States and then moves on to consider some nontraditional means for increasing the supply of educated workers.

A potentially important impediment to the growth in educational attainment of the US population is the dramatic rise in college tuition. Tuition and fees, even net of institutional aid, grew by 100 percent between 1987 and 2010. This rise dwarfs even the rise in health care costs. In "Accounting for the Rise in College Tuition," Gordon and Hedlund seek to understand the sources of this rise since 1987.

Assessing the importance of the leading factors would be difficult to do with purely empirical methods, since tuition and many of the candidate factors are all trending up together. To answer the question, Gordon and Hedlund thus turn to quantitative methods. In particular, they specify a theoretical model that embeds a college sector in an open-economy model. They then calibrate the model to match key data moments since 1987 and use it to assess the sources of the rise in college tuition between 1987 and 2010. They find that demand changes due to changes in financial aid can account for virtually all of the rise in tuition. The rise in the college wage premium (due to skill-biased technological change) alone can account for 20 percent of the rise. In contrast, they find a *negative* role for Baumol's cost disease. This surprising result becomes clearer once one considers equilibrium effects: while the cost disease might explain tuition increases at a *given* university, in equilibrium students are substituting into cheaper universities, so this factor does not raise *overall* tuition.

The Gordon and Hedlund chapter represents a serious first step in using quantitative models to study the sources of the rise in college tuition. As they acknowledge, however, the model is very stylized in some dimensions and misses some potentially important features. Thus, the results are only suggestive at this point. However, their analysis is a good foundation for future research using quantitative methods.

The role of education in innovation and the production of output has been a general theme of this conference. "Online Postsecondary Education and Labor Productivity" by Caroline M. Hoxby turns this question around and looks at one of the most notable innovations in higher education itself. Enrollment in online education has experienced explosive growth in recent years and the online postsecondary education sector (OLE) has been hailed as the wave of the future by its enthusiasts. Hoxby takes a close look at the evidence, examining both its pros and cons in comparison with traditional "in-person" brick-and-mortar institutions (B&M), including those that are less "competitive" and also have an online presence. Hoxby uses longitudinal data from the IRS on nearly every person who engaged substantially in online postsecondary education between 1999 and 2014 (supplemented, in places, by National Center for Education Statistics [NCES] data). Her basic objective is to calculate the return on investment (ROI) to see if students recoup enough in additional discounted lifetime wages to cover the cost of the OLE, inclusive of the opportunity cost of time. In addition, the study computes a social return that includes the cost of public subsidies.

This first in-depth study of the returns to online education uncovers many interesting, and sometimes surprising, dimensions of online education. For example, she finds that the undergraduate tuition paid by the OLE students is actually higher than that paid by those in *nonselective* brick-and-mortar institutions. Yet, the resources devoted to students in OLE are lower. Estimates of ROIs suggest that the earnings of most online students do not increase by enough to cover even their private costs, though there are exceptions. Moreover, while online enrollment episodes do usually raise students' earnings, it is almost never by an amount that covers the *social* cost of their education.

Last, but by no means least, in the topic of skill supply is the important issue of immigration as a source of supply for the skills needed in high-technology employments. The chapter "High-Skilled Immigration and the Rise of STEM Occupations in US Employment" by Hanson and Slaughter explores the contribution of immigrants to employment in US STEM fields. The STEM workers overall tend to have much higher formal education than the average worker. Moreover, as previously noted, Hanson and Slaughter show that the immigrant share of hours worked in the STEM occupations has increased to the point that prime-age workers with advanced degrees now account for almost half the total hours worked, more than double the proportion of the hours worked in 1980.

The foreign-born share of STEM employment is higher than for non-STEM employment. Hanson and Slaughter consider possible explanations for the foreign-born comparative advantage in STEM fields. The hypothesis with the most support is that it is relatively more difficult for foreign-born higher-educated workers to gain entry into nontechnical occupations because many of those occupations require elevated knowledge of the subtleties of US culture that are important for face-to-face communication with customers. The authors compare wages and find that, while the foreign born have significantly lower wages than natives in the nontechnical occupations, the foreign born have similar wages to natives in the STEM occupations. Hanson and Slaughter's findings suggest that, to the extent that STEM occupations are important for technological change and growth in the United States, then immigrants with college and advanced degrees have played an important role in US growth.

We also recommend the comments made by discussants of the various chapters. The discussants are eminent experts and their discussions are well worth reading as contributions in their own right.

Conclusion

The chapters in this volume cover a wide range of issues drawn from different literatures within the field of economics. The goal was to bring together a mix of researchers in order to address an important question that spans these literatures: How will current trends in human capital formation affect future US growth? The macroeconomic literature on the sources of growth has long recognized the potential importance of human capital accumulation for growth but has only begun to study the microeconomic mechanisms of that accumulation. On the other hand, the microeconomic literature on education and human capital formation studies many detailed aspects of skill supply and demand at the microeconomic level but seldom draws out the implications for the future of macroeconomic growth. While there is still considerable debate over many of the issues touched on in this volume, we believe that the research presented is a significant step toward linking these research areas in a way that informs the larger questions of how well students are being prepared for the current and future world of work, and whether this preparation will sustain the growth of an increasingly knowledge-based economy.

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