

**Education, Skills, and Technical Change, and Future U.S. GDP Growth:
An Introduction and Overview**

Charles Hulten and Valerie Ramey

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I. Overview

The growth in future living standards in the U.S. will likely depend to a significant degree on the continued evolution in the “knowledge” segments of the economy. These are the high valued-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, nano-technology, 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 work force that cannot play this role may limit the rate of innovation and may slow the growth in living standards.

A century ago the U.S. became a world leader in the expansion of secondary and tertiary education, a development that helped propel U.S. 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 U.S. growth has slowed in recent decades and the slowdown may last into the future. Moreover, the long-standing problem of the *quality* of the U.S. primary and secondary education system has continued to be a

source of concern, despite decades of efforts to improve the U.S. education system. According to the OECD's 2015 PISA survey of 15 year olds, the U.S. 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 aged 16-65 in 24 countries. The literacy results for the U.S. population are slightly below those of the OECD as a whole, but are considerably below the OECD in numeracy. Indeed, only a third of U.S. 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 U.S. 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 has been stagnant in recent years.

The trend in human capital formation and its interaction with technology on the future of U.S. growth are the subject of the Conference on Research in Income and Wealth conference *Education, Skills and Technical Change: Implications for Future U.S. GDP Growth*, held in Bethesda, Maryland on October 16th and 17th, 2015. This conference volume contains twelve papers ranging over various aspects of this question, with discussant comments for many of the papers. 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 "non-cognitive 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 how human capital affects economic growth and review the channels through which the skills and education of the labor force impact GDP growth. We then offer our own summary assessments of many of the salient issues, before providing a brief summary of the papers themselves.

¹ OECD (2016), *Snapshot Table*, page 5.

² OECD (2013), Tables A2.1 and A2.5

A. 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 the 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 field of education generally see educational attainment and human capital development as critical factors in the process of economic growth. Hanushek and Woessmann start their 2015 book on *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*” (p. 1). 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 knowledge of the knowledge distribution that were responsible for much of the technological development that drove the Industrial Revolution. David Landes, in his 1998 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*” (p. 276).

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 over 25 with college degrees, increased from around 5% in 1950 to 30% in 2010 and two-thirds of high school graduates went on to some form of tertiary education in 2012 according to Census data, up from 50% in 1975.³ This increase was driven, in part, by the growing wage premium for a college education documented in the 2010 work of Goldin and Katz and by Valetta writing in this

³ U.S. Census Bureau, *CPS Historical Time Series Tables*, “Table A-1: Years of School Completed by People 25 Years and Over, by Age and Sex: Selected Years 1940 to 2012”, 2015.

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 U.S. in 2011 was nearly 7% of GDP.⁴

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 post-graduate and professional education. These are issues that high income societies like the U.S. 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.

B. The Channels Through Which Human Capital Affects GDP Growth

Economic growth is a complex process influenced by many factors, and education is a multi-faceted process that affects growth through multiple channels. As a backdrop for the material presented in the various papers 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 this effect can be estimated using the growth accounting method pioneered by

⁴ These estimates are from Table 236.55 of the 2013 Digest of Educational Statistics.

Jorgenson and Griliches in their path breaking 1967 paper and employed by the BLS in their Multifactor Productivity program. The papers by Jorgenson, Ho, and Samuels and Bosler, Daly, Fernald, and Hobijn in this volume provide estimates based on this method showing that education has made a relatively small contribution to growth in recent years.

(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 non-routine 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 micro structure 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 the growth of these more technologically (Hulten, writing in 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 emphasize in their 1966 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 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 arising from the inability of innovators to completely protect their property rights against diffusion to other users (Romer (1986, 1990)).

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

(5) Social Capital. Education is part of foundational infrastructure that sustains social, political, and economic institutions. This mechanism is perhaps not so much a specific channel as 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 papers 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.

C. The Supply and Demand for Skills and Education: An Overview

Individual papers are summarized briefly in Section II, but, before going there, we offer a summary assessment of what we see as the main points. They reflect our reading of the papers, 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 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 non-routine 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 socio-economic status of the family also matters (see, for example, 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 the 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 non-cognitive skills.

(3) Much of the recent focus on the demand side of skill development has been on the higher-order cognitive and non-cognitive 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 non-cognitive “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 addressing 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 2014 study by Abel and Deitz 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 U.S. stands out in the PIACC international comparison in its propensity to reward those with the highest skills (Broecke et al. in 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 et al. (2016) and the paper in this volume by Valletta, as well as the comment on this paper by Autor).

⁶ See Heckman et al. (2006) and Heckman et al. (2016)

(8) Immigration is an important source of the supply of highly skilled and educated workers, and is particularly important in the STEM areas. Hanson and Slaughter, writing in this volume, report that the foreign-born share of STEM employment in 2013 was approximately 20% among those with bachelor degrees, 40% among those with master's degrees, and 55% among PhDs.

Expressed in terms of hours among prime-age workers (those 30 to 45 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 been an important source of entrepreneurship, according to the 2017 study by Kerr and Kerr.

(9) The quality of education matters as well as the quantity. In this regard, the success of the U.S. education system in preparing students with the skills needed for the economy of the 21st century gets a mixed report card. According to 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 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 U.S. higher education is very high in international comparisons, but there are still problems facing college students: rising tuition (see the paper 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, this volume). On the other hand, the educational outcomes at the K-12 level revealed by the 2015 NAEP 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

⁷ U.S. Census Bureau, *CPS Historical Time Series Tables*, 2015, Table A.1.

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% in mathematics. These deficits have persisted over time and they do not bode well for future employment in an increasingly technological world economy.

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 the U.S. youth is not being well prepared for the needs of the knowledge economy and the affluence it conveys, or for the remaining mid-skill jobs that in the past have provided middle-class affluence. While higher education, with its large wage premium, is a pathway to higher economic 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.

II. Summary of the Papers in the Volume

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

A. 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. They are followed by a general discussion of the issues by Douglas Elmendorf, whose unique perspective as former head of the CBO illustrates the policy-relevance of the questions being asked.

The first two papers 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, defined as the shift in the composition of the 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.

“Education, Participation, and the Revival of U.S. Economic Growth” by Jorgenson, Ho, and Samuels analyze the recent past and projected future of labor quality growth and overall GDP growth, using a newly constructed KLEMS 65-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 paper “The Outlook for U.S. 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, etc. 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, 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 U.S. will finally start showing up in aggregate labor quality growth.

The paper by Hulten, "The Importance of Education and Skill Development for Economic Growth in the Information Era", is the third of the papers in the volume that deals 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 paper 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 are linked to the higher-order labor skill need

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 paper’s most salient result: 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, and in a way that assigns a greater importance to labor skills and education. Hulten offers an activity-analysis interpretation of the Information Revolution in which the shift toward complex-skills and education was a necessary enabler of the significant contribution by knowledge-based capital, because skilled labor and complex knowledge capital are strong complements.

B. 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 papers in this section shed light on the issue of this match and the demand for skills. The first paper 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 college graduates. Unemployment rates by education are readily available, but *underemployment* rates are not part of the standard government statistics. Abel and Deitz construct new series on underemployment rates of recent college 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. Abel and Deitz 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 college 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 nine 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 pre-production 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 21st Century U.S. economy. The bottom line is that three-quarters of all current jobs do not *require* a four-year college degree.

Additional results suggest 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 of jobs available for individuals with low education and skill levels, those jobs pay much less than those with higher education and skill levels.⁹

C. Skills, Inequality and Polarization

The papers in the last sections went far beyond the standard practice of equating labor quality or skill with years of education. The papers in this section consider additional dimensions. One paper branches out to consider non-cognitive skills and the other three consider the distribution of skills rather than just the average.

“Non-Cognitive Skills as Human Capital” by Lundberg discusses both what we know about the importance of non-cognitive 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 2000s showed that it might be valuable for economists to broaden their concept of human capital to include “non-cognitive skills” in the form of personality traits. As Lundberg points out, however, measures of non-cognitive skills are not always reliable in all applications. She cites a lack of consensus on what non-cognitive skills really are as well as a lack of a consistent set of metrics across studies. Part of her paper points out the current gaps and what would be needed to consider the role of non-cognitive 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 non-cognitive skills across different environments.

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.

To illustrate the issues involved, Lundberg uses the NLSY97 and the Add Health surveys to estimate the relationships between non-cognitive skills and outcomes. A number of interesting results emerge that show the difficulty of interpreting results. First, the correlation between various measures of non-cognitive skills is surprisingly low. Second, the important and statistically significant effects of many of the non-cognitive 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 non-cognitive 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 non-cognitive skills in predicting outcomes such as crime are not necessarily robust to adding other measures of non-cognitive skills.

Overall, Lundberg's paper highlights the fact that non-cognitive 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 paper is very useful for pointing out the key gaps that need to be filled in the literature.

The next paper in the session, 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 paper 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 U.S. has one of the lowest average levels of adult skills and but one of the highest dispersions of skills. Moreover, the U.S. 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 U.S. are much more important than differences in the *endowment of skills* in accounting for the inequality of wages in the U.S. relative to other countries. Overall, this paper 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 U.S. remains high, as evidenced by the high skill premium.

Erik Hanushek's paper "Education and the Growth-Equity Tradeoff" considers a number of the 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 co-authors, 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 paper "Recent Flattening in the Higher Education Wage Premium: Polarization, Deskilling, or Both?" focuses on trends in wage premia. He particularly studies possible sources for the documented flattening in the returns to education. Since 1980, educational wage premia 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. One hypothesis 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 non-routine, non-cognitive jobs which 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 premia 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 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 premia 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 scarcer. 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.

D. The Supply of Skills

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

A potentially important impediment to the growth in educational attainment of the U.S. 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 paper 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. "The Returns to Online Postsecondary Education" 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 NCES data). Her basic objective is to calculate the "Return on Investment" to see if students recoup enough in additional discounted life-time 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 *non-selective* 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 paper “High Skilled Immigration and the Rise of STEM Occupations in US Employment” by Hanson and Slaughter explores the contribution of immigrants to employment in U.S. STEM (Science, Technology, Engineering and Math) fields. 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 non-technical occupations because many of those occupations require elevated knowledge of the subtleties of U.S. 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 non-technical 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 U.S., then immigrants with college and advanced degrees have played an important role in U.S. growth.

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

III. Conclusion

The papers 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 U.S. 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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