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MEASURING HUMAN CAPITAL

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ABSTRACT

There are many reasons to want measures of countries' investments in human capital and especially their investments in formal education. We review the existing literature on the measurement of human capital. Broadly speaking, economists have proposed three approaches to the measurement of human capital—the indicator approach, the cost approach and the income approach. Studies employing the indicator approach have used single measures such as average years of schooling or created indexes of multiple measures as human capital proxies. The cost approach values human capital investments based on spending. The income approach values human capital investments by looking forward to the increment to expected future earnings they produce. The latter two approaches have the significant advantage of consistency with national income accounting practices and measures of other types of capital, but there are also challenges to their implementation. Measures based on the income approach typically yield far larger estimates of the value of human capital than measures based on the cost approach. We outline possible reasons for this discrepancy and show how changes in assumptions can reconcile estimates based on the two approaches.

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In describing the role of “fixed capital” in an economy, Adam Smith (1776, Book II, Ch. 1) considered four categories. The first three were “machines and instruments of trade,” “profitable buildings,” and “improvements of land.” The fourth type was what economists now refer to as “human capital,” which Smith described as consisting

> … of the acquired and useful abilities of all the inhabitants or members of the society. The acquisition of such talents, by the maintenance of the acquirer during his education, study, or apprenticeship, always costs a real expence, which is a capital fixed and realized, as it were, in his person. Those talents, as they make a part of his fortune, so do they likewise of that of the society to which he belongs. The improved dexterity of a workman may be considered in the same light as a machine or instrument of trade which facilitates and abridges labour, and which, though it costs a certain expence, repays that expence with a profit.

On this point, the national income and product accounts have not yet caught up with Adam Smith. The national accounts developed by Simon Kuznets and others in the 1930s and 1940s treated only investments in physical capital as additions to the capital stock. Conceptually, Kuznets recognized that this decision resulted in the omission of important investments in the nation’s productive capacity. Writing in 1961 (Kuznets 1961, p. 390), he commented that

> (F)or many purposes—particularly the study of economic growth over long periods and among widely different societies—the concept of capital and capital formation should be broadened to include investment in the health, education, and training of the population itself, that is, investment in human beings.

While believing that, in concept, human capital should be measured, Kuznets defended its omission from the accounts on two practical two grounds—first, that measuring human capital investments would be difficult and, second, that it would be hard to distinguish activities undertaken for the purpose of adding to productive capacity from those undertaken for enjoyment.

There are many reasons to want to measure investments in human capital and the resulting stock of human capital. The development of human capital is central to modern theories of economic growth (for example, Lucas 1988, Romer 1990, Barro and Sala-i-Martin 1995). Understanding how investments in the skills and abilities of the population contribute to differences in economic activity over time and across countries requires good measures of the resulting human capital and the services it provides. Assessing the sustainability of economic activity also requires measures of investment in human capital. In a country in which the capital stock is depleted more rapidly than it can be replaced, productive capacity will fall, leading eventually to declining output. Failure to recognize net additions to the capital stock in the form of investments in human capital could lead to erroneous conclusions about the evolution of a country’s productive capacity. The fact that spending in areas like education and health care absorbs large shares of the resources of every developed economy is another reason to want good measures of the development of human capital.

Investment in human capital—the skills and experience possessed by an individual or population viewed in terms of their productive value—may take many forms (Abraham and Mackie 2005). The time that parents spend with their children during the early childhood years can be considered an investment in the development of the children's cognitive, emotional, and social abilities. Formal education, from the primary grades through college and postgraduate studies, represents a further investment in the development of students' capacities. After leaving school, individuals may engage in structured training or less formal learning on the job. More broadly, one can consider medical care, diet, and exercise forms of investment in human capital. Although there have been efforts to measure investments in human capital writ broadly, investments in formal education have been of particular interest. Our primary focus, too, will be on the measurement of human capital attributable to formal education, though we also will touch on the development of more comprehensive human capital measures.

Three Approaches to Measuring Human Capital

In the US national income and product accounts, the amounts that households spend on nursery school, elementary and secondary education, vocational education, and higher education appear as part of personal consumption expenditures. The costs of the education services that non-profit schools and colleges provide to households, over and above the revenues received in the form of tuition and fees paid for those services, also appear as part of personal consumption expenditures. The accounts record government spending on education, net of tuition revenues, separately from spending by households and nonprofits as a component of government consumption.[1]

Personal consumption spending and government spending on education as recorded in the existing accounts can be added together to produce a measure of overall education spending. Because the accounts do not consider the time that students and their parents spend on their schooling, however, that measure will understate the resources devoted to formal education. Further, because the accounts treat education spending as consumption rather than investment, they provide no information on the value of the stock of human capital attributable to investments in education or on changes in the value of that stock over time.

Three broad approaches have been taken to measuring investments in formal education and the resulting human capital stock—the indicator approach, the cost approach and the income approach (Le, Gibson and Oxley 2005; Jones and Fender 2011; UNECE 2016). The indicator approach attempts to capture a country's investments in human capital using measures such as school enrollment, average years of schooling, or adult literacy. The cost approach values investments in education-related human capital based on education spending. The income approach values these investments by looking forward to the increment to expected future earnings attributable to current school enrollments and calculating the present value of those

[1] The costs incurred by nonprofit educational institutions and government incorporate estimates of implicit spending in the form of depreciation of their physical plant and equipment. Bureau of Economic Analysis (2021) provides details on the treatment of education spending in the national accounts.

added earnings. Table 1 briefly summarizes the three approaches, gives examples of studies using each them, indicates the data required for implementing the approaches, and outlines each approach's pros and cons. In the following pages, we discuss the indicator, the cost and the income approach in turn.

The indicator approach to measuring human capital

Of the three approaches to measuring investments in human capital generally and education capital specifically, the indicator approach is the most straightforward. Indicators commonly are related either to the flow of investments in education capital (as measured by, say, school enrollments) or to the stock of education capital (as proxied by, say, adult educational attainment or adult literacy). The indicator approach provides a relatively parsimonious way to compare investments in human capital across countries.

Perhaps the best-known indicator dataset is the one developed by Barro and Lee (1993, 2001, 2013, 2021). The latest version of the Barro and Lee dataset contains information on educational attainment for 146 countries. It reports the share of the population with each of seven levels of education—no formal education, incomplete primary, complete primary, lower secondary, upper secondary, incomplete tertiary, and complete tertiary—by five-year age intervals over the period from 1950 through 2015. The dataset also contains measures of mean years of schooling. The Barro-Lee measures are based primarily on national census data and, in some cases, have suffered from apparent inconsistencies over time. Seeking to resolve these inconsistencies, several teams of researchers have proposed alternative educational attainment series as alternatives to the Barro-Lee schooling measures (for example, Cohen and Soto 2007, Cohen and Leker 2014, de la Fuente and Doménech 2015; Goujon et al. 2016).

Other prominent indicator-based human capital measures are weighted indexes based on multiple underlying components that encompass more than just formal education. The most recent version of the World Bank's Human Capital Index (HCI) covers 174 countries. The dimensions incorporated in the HCI include the probability of survival to age five; expected years of school; harmonized test scores; the fraction of children under age five whose growth is not stunted; and adult survival rates (World Bank 2020). As another example, the World Economic Forum's Global Human Capital Index (GHCI), last published in 2017 for 130 countries, incorporates an even larger set of indicators. These capture not only what its authors term development (formal education of the next generation workforce and upskilling of the current workforce) and capacity (level of formal education resulting from past investments), but also knowhow (breadth and depth of specialized skills in use at work) and deployment (skills application and accumulation among the adult population) (Samans et al. 2017).

One problem with indexes like the HCI and GHCI is the unavoidable arbitrariness of the weights attached to the various index components. Rather than using the index, researchers may choose to employ the underlying index components.

Table 1: Approaches to the Measurement of Human Capital

Approach	Examples of Relevant Studies	Data Requirements	Pros and Cons
Indicator: Measure or measures indicative of a country's investment in or stock of human capital; if multiple measures, weighted to form an index.	Barro and Lee 1993, 2001, 2013, 2021 (average years of schooling) World Bank 2020 (World Bank Human Capital Index; considers expected years of schooling, test scores, prevalence of stunted growth, and child and adult survival rates) Samans et al. 2017 (World Economic Forum Global Human Capital Index; considers measures that include school enrollment, educational attainment, literacy, labor force participation, and skill mix of employment)	Survey, census or administrative data for chosen metric(s) that are consistent across countries and over time	(+) Relatively straightforward to construct and explain (-) Schooling measure(s) may mean different things in different contexts (-) Weights for indicators that combine multiple measures unavoidably arbitrary (-) Not compatible with national accounts or measures of other types of capital
Cost: Current gross investment equals direct spending plus estimated value of unpaid time devoted to human capital development; stock equals sum of appropriately depreciated past investments.	Kendrick 1976 (expanded accounts encompass investments in child rearing, formal education, training, health and geographic mobility) Eisner 1978, 1985, 1989 (Total Incomes System of Accounts encompasses investments in formal education, training and health) Gu and Wong 2015 (recent cost-based estimates of investments in formal education in Canada; do not report stock estimates)	School enrollment by age, sex and type of schooling (e.g., grade level); estimated numbers for other human capital investments Direct spending for formal education, training and other human capital investments Value for time devoted to human capital investment (e.g., student time in formal education, employee time in training) Quantity indexes or deflators for nominal spending series	(+) Monetary measure suitable for integration into national accounts and compatible with measures of other types of capital (-) Relatively demanding data requirements, especially for investments other than in formal education (-) Sensitive to assumptions about value of nominal spending in different periods and rate at which investments depreciate (-) Captures resources devoted to formal schooling and (if applicable) other human capital investments, not necessarily the productive value of that spending
Income: Current investment equals year-over-year change in present value of future labor income; stock equals present value of current population's future labor incomes.	Jorgenson and Fraumeni 1989, 1992a, 1992b (estimates of investment through formal education and additions to population, and of value of stock of human capital) Christian 2010, 2014, 2017; Fraumeni and Christian 2019 (extend and update earlier Jorgenson and Fraumeni work)	School enrollment by age, sex and type of schooling (e.g., grade level) Population by age, sex and educational attainment Earnings by age, sex and educational attainment Mortality rates by age and sex	(+) Monetary measure suitable for integration into national accounts and compatible with measures of other types of capital (-) Relatively demanding data requirements (-) Sensitive to assumptions regarding future growth in earnings, appropriate discount rate for future earnings, and, for formal education, how not completing a year of schooling affects later educational attainment

The indicator approach has been useful. Data on school enrollments and educational attainment not only are valuable in themselves, but also are necessary inputs to the full development of the other two approaches to the measurement of education capital—the cost and income approaches. Various studies have used indicators based on educational attainment in empirical analyses of economic growth. Some of these studies simply include mean years of schooling in cross-country growth regressions, effectively treating the productive value of additional years of schooling as a constant. Others make use of information on years of schooling, but allow the returns to education to vary with the educational attainment of the population or over time (Botev et al. 2019).[2]

Though valuable, the indicator approach also has limitations. While a measure such as mean years of schooling may help with understanding differences in productivity over time or across countries, depending on the content and quality of the education provided, a year of schooling may mean different things at different times and in different countries. This problem can be addressed to some extent by using proxies such as student-teacher ratios or test scores to adjust for varying educational quality (Fraumeni et al. 2009, UNECE 2016). In addition, the value of the human capital produced through formal education may depend on other factors, like a country's institutions and social infrastructure (Hall and Jones 1999, Caselli and Ciccone 2019).

On their own, measures of educational attainment cannot provide answers regarding the value added of the education sector. Perhaps most important, the indicator approach is inherently incompatible with the treatment of other types of investment in the national accounts. Monetary measures compatible with national income accounting practices, such as the cost-based and income-based measures we consider next, are more appropriate for any analysis that considers human capital investment in the context of investment and capital accumulation more broadly.

The cost approach to measuring human capital

Tracking changes in nominal education spending over time is relatively straightforward. Translating a data series for nominal spending on education into a real spending series, and then using those data to construct estimates of capital depreciation and the stock of education capital, is considerably more challenging. Data limitations make carrying out these tasks for other types of human capital investment even more difficult. Perhaps for these reasons, relatively few researchers have adopted the cost-based approach to measuring human capital. During the 1970s and 1980s, Kendrick (1976) and Eisner (1978, 1985, 1989) developed expanded economic accounts that incorporated human capital investment based on a cost approach. Their efforts were ambitious, encompassing not only investments in formal education but also investments in job training, health, and, in the case of the Kendrick estimates, geographic mobility and child rearing. More recently, Gu and Wong (2015) have developed both cost- and income-based estimates of investments in formal education for Canada.

[2] Incorporating information on the returns to education creates some similarities between these approaches and the income approach discussed below.

A recent international task force operating under the auspices of the United Nations Economic Commission for Europe has developed guidelines for satellite accounts that would systematically compile information on the costs of education and training. These satellite accounts would provide much of the information needed to construct cost-based measures of real education investment and the stock of education capital, should a national statistical office wish to do so (UNECE 2020). Here, we discuss several of the challenges in developing such measures—converting nominal expenditures on education to real terms; estimating a capital stock based on past expenditures; and the issues posed by the valuation of time spent by children and parents in education and by immigration and emigration.

Understanding how investments in education capital have evolved over time and producing measures of the current capital stock requires information on *real* education spending, as opposed to nominal spending. The standard approach to converting from nominal to real spending is to use an index of output prices to adjust spending amounts for the effects of inflation. Because governments do not sell education services at market prices, however, that approach will not work in this area. An alternative approach for estimating the real value of government output is to deflate spending by an index of the prices of *inputs* for education—like teacher salaries— but this has the drawback of assuming that the technology for transforming education inputs into education outputs does not change over time. For government output that has a market counterpart, deflators could be constructed using private sector prices, but even when the government and the private sector appear to provide similar services, they may not be truly comparable.

National accounting experts who have considered how best to measure nonmarket output, including government output, generally have concluded that the best approach is to use a quantity index for apportioning nominal changes in spending into the piece that presents real output change versus the piece that is due to changes in prices (European Commission et al. 2009, UNECE 2016). In the case of education, the challenge is to produce a quantity index of real output that can be tracked over time.

A simple way to construct a quantity index for education would be as follows. Start with the number of students educated in a base period. Divide these students into "types," for example, by grade. Get information on the share of education spending going to each type of student in the base year. For each future year, get data on the number of students of each type and use that information to construct a "quantity relative" equal to the number of that type in the later period divided by the number in the base period. Use the cost weights from the base period to sum up these quantity relatives for the different types of students. The result will be a base-weighted (or Laspeyres) quantity index.[3] The changes in nominal spending over time then can be divided into the real change in output (the portion of the change accounted for by the change in the quantity index) and the change in price (the piece that is left over).

[3] Index number formulas such as the chained Fisher or chained Tornqvist formula generally are preferred to the Laspeyres formula, but quantity indexes constructed using these formulas could be used in the same fashion to estimate real expenditures by period. For a discussion of alternative index formulas and their properties, see Diewert (in process).

These calculations implicitly assume that the quality of education for students within a particular group does not change over time, a necessary assumption so that cost-share-weighted sums of the quantity relatives for the different groups of students can be used to measure education output in the later period compared to the earlier period. As mentioned in discussing the indicator approach, it may be possible to improve the measures of real output over time by incorporating proxies for the quality of education into the analysis, although with a tradeoff of additional complexity.

Given data on past real investments in capital, one can use the "perpetual inventory method" to develop an estimate of the current value of the resulting stock of capital. Except for automobiles, which are valued directly, this is the approach used in the existing national income and product accounts for valuing the current physical capital stock (Katz 2015). The basic idea is that the change in the value of the capital stock from one year to the next equals new investment spending minus an adjustment for any year-over-year decline in the value of the previously existing capital stock. The key question is how much spending on capital in earlier periods contributes to the stock of capital in the present.

Physical capital depreciates with age both because it becomes less efficient (for example, because it requires more maintenance downtime) and because its remaining useful lifetime is shorter. Sales of used assets provide direct evidence on the depreciation of physical capital over time. Similarly, human capital may depreciate both because of changes in the value of the skills a person possesses (for example, skills acquired in school may become rusty over time) and because expected remaining lifetimes become shorter as people age. In contrast to physical capital, though, no direct evidence is available for quantifying how human capital depreciates. Past estimates of the stock of human capital based on the cost approach have made differing assumptions about depreciation profiles, but there is little empirical basis for choosing among them. Eisner (1978), for example, assumed straight-line depreciation, that is, that a human capital asset with a useful life of T years loses 1/T of its initial value each year. Kendrick (1976) assumed double-declining balance depreciation, meaning geometric depreciation at a rate equal to twice that implied by straight-line depreciation in the first year of the asset's life, switching over to straight-line depreciation at the point when that became larger than the depreciation implied by the double-declining balance method. This difference in the choice of depreciation method explains why Eisner estimates larger values for net investment (gross investment minus depreciation) in human capital than Kendrick.

Two additional points about the cost-based approach to valuing the human capital created through formal education are worth noting here. First, as already remarked, although considerable information on education spending is available from the existing national income and product accounts, they omit the value of the hours that students spend in school or studying, together with the value of the hours spent by parents in supporting the students. The value of this unpaid time is an important part of the true cost of formal education.

The appropriate valuation for the time students devote to their own education is their opportunity wage—the amount that they could have earned had they been working rather than in school. Because the services provided by parents could be performed by someone else, the right wage for valuing that time is a replacement wage—what it would have cost to hire someone else to do the same work—rather than an opportunity wage (Abraham and Mackie 2005).

In the United States, reasonable estimates of the hours students devote to schooling can be constructed using data on school enrollments by grade level, attendance rates and academic calendars compiled by the National Center for Education Statistics (NCES). Compulsory schooling and child labor laws typically prevent younger children from working for pay, so it is reasonable to set the opportunity cost of younger children's time to zero. For older students, however, the earnings foregone by remaining in school are a significant part of the cost of their education. Beginning in 2003, estimates of the time that parents spend on activities related to children's education are available from the American Time Use Survey. As discussed later, the hours parents devote to children's formal education—and thus the value of that parent time—are modest relative to the value of the time students devote to their own education.

An additional complication in valuing the time that students devote to their education is that, in addition to contributing to a person's human capital, education also may be something that people enjoy and thus a form of consumption. Conceptually, to the extent that being in school is more enjoyable than working at a job, some portion of the opportunity cost associated with the time students devote to formal education should be treated as consumption rather than investment. On the other hand, some students may find being in school particularly unpleasant. In that case, the adjustment should go in the other direction, implying a true cost of education that is higher than estimated based on direct expenditures and the opportunity cost of students' time. One interesting recent study suggests that students derive significant positive consumption value from being in school (see Gong et al. 2021), but this is very much an open area for further research.

A final comment about the cost approach for measuring human capital is that estimates of the stock of education capital based on past education spending do not account for the effects of immigration and emigration. Most immigrants arrive as adults, meaning that, on arrival, they embody a significant amount of human capital acquired elsewhere. In 2019, 13.7 percent of the resident population of the United States had been born somewhere else (Batalova, Hanna, and Levesque 2021). A full assessment of how a country's stock of human capital evolves would need to account for the additions to the stock through immigration and losses through emigration.

The income approach to measuring human capital

In a frictionless market that operates with complete information, the price that someone should be willing to pay for a marketable asset is equal to the present value of the future returns that asset will generate. In a series of seminal papers, Jorgenson and Fraumeni (1989, 1992a, 1992b) adapt the spirit of this approach to value investments in formal education (and other forms of human capital)—that is, to calculate the stock of human capital by estimating the present value of the future returns that workers will generate.

Using the Jorgenson and Fraumeni approach to estimate the value of the stock of human capital requires data on the number of people in the population by age, sex, and level of education. The calculations also require estimated earnings for each age/sex/education cell, together with the probabilities of survival from one year to the next. Jorgenson and Fraumeni begin with current figures on the earnings of people in different age/sex/education cells and assume that the overall level of earnings will grow by some percentage *g* each year, but that the relative earnings of people in the different age/sex/education cells will not change. Future earnings are discounted to capture present values. Here, we first describe the basics of the Jorgenson and Fraumeni income approach, and then discuss three challenges in its implementation.[4]

As a starting point to determining the expected present value of future earnings for people of a given age, sex and level of education, Jorgenson and Fraumeni begin by calculating the present value of lifetime earnings for the oldest individuals in their data set and work recursively backwards. Suppose that the oldest working people are age 75. The present value of market income for someone in this group is just equal to market income at age 75. Now consider the present value of lifetime earnings for a person age 74. This equals current earnings as of age 74 plus the expected present value of future earnings as of age 75. Jorgenson and Fraumeni continue working backwards in the same fashion to younger age groups. In this way, they estimate expected future earnings for everyone in the population, differentiated by age, sex, and level of education.

Investments in formal education are valued based on projections of the amount they will add to future earnings. The total value of the human capital stock may grow from one year to the next due not only to formal education, but also due to births or in-migration. Conversely, the value of total human capital can decline from one year to the next due to aging (which reduces years of anticipated future earnings for the existing population), death, and outmigration.[5]

In contrast to the cost approach, the income approach does not require explicit assumptions about the rate of depreciation of human capital, as that can be backed out of the calculations by looking at how the expected present value of earnings changes as people age. It does require other assumptions, including assumptions about the growth rate of the overall level of future earnings and the intertemporal discount rate. Typical assumptions regarding the annual growth of labor income and the discount rate for future earnings are in the range of 1 to 2 percent per year for the growth rate of future earnings and 4 to 5 percent per year for the intertemporal discount rate.

The choice of discount rate is of particular interest in part because the discount rate that a social planner would apply may be substantially lower than that applied by individuals making decisions about investments in education. There are two reasons for this. First, because

[4]Klenow and Rodrıguez-Clare (1997) and Arrow et al. (2012) lay out a different approach for calculating the present value of the stream of lifetime income attributable to investments in human capital and valuing the stock of human capital. The United Nations Environment Programme has employed this method for its Inclusive Wealth Report (Managi and Kumar 2018), but studies applying the income approach to valuing human capital more commonly have adopted the methods developed by Jorgenson and Fraumeni.

[5] The capital stock also may be revalued from one period to the next if there are changes in projected earnings for people of given age, sex and education.

individuals cannot diversify their investment in formal education, they will correctly view such investments as risky. From the perspective of the society as a whole, however, investment in formal education is diversified across individuals and thus considerably less risky. Second, individuals often appear time-inconsistent with regard to their educational decisions, choosing lower levels of investment in education than they later wish they had made (De Genova 1992). To overcome this time inconsistency, a social planner should place more weight on future utility than would individual decision-makers, leading to a social discount factor lower than the individual discount factor (Caplin and Leahy 2004).

Estimates of the value of investment in education are quite sensitive to choices regarding the earnings growth rate and discount rate. Jorgenson and Fraumeni (1992b) report that the value of investments in formal education, including both market and nonmarket returns, was $5.0 trillion in 1986 (in 1986 dollars) assuming an annual earnings growth rate of 2 percent and a discount rate of 4 percent. This total falls nearly by half to $2.7 trillion assuming an earnings growth rate of 1 percent and a discount rate of 6 percent. Christian (2014) reports that, in 2009, the market value of gross investment in human capital calculated using the standard Jorgenson and Fraumeni approach was $21.0 trillion (in 2009 dollars) assuming an annual earnings growth rate of 2 percent and an annual discount rate of 4 percent. Assuming instead an annual growth rate in earnings of 1 percent and an annual discount rate of 12 percent, this falls to $3.1 trillion.

A first challenge in implementing the income approach is how to value the human capital of those who have not yet completed their education. In the Jorgenson and Fraumeni calculations, persons age 35 through 75 do not enroll in school, but individuals between ages 5 and 34 may choose to acquire additional education. In describing how they project future labor income for a person with either the highest or the next-highest number of years of education, Jorgenson and Fraumeni (1992b, p. 309) explain:

> For an individual of a given age and sex enrolled in the highest level of formal schooling, which is the 17th year of school or higher, lifetime labor income is the discounted value of labor incomes for a person with 17 years or more of education. For an individual enrolled in the 16th year of school, lifetime labor income includes the discounted value of labor incomes for a person with 17 years of formal education or more, multiplied by the probability of enrolling in the 17th year of school, given enrollment in the 16th year... It also includes the discounted value of labor incomes for a person with 16 years of education, multiplied by one minus this probability, which is the likelihood of terminating formal schooling at 16 years.

For an individual of any given age and current schooling level, the value of investing in an additional year of schooling is treated as equal to the difference between the expected present value of labor income for a person who completes the extra year of schooling versus that for someone who does not. This includes any differences in future earnings related to the fact that those who complete the extra year of schooling are more likely than those who do not to continue on to acquire further schooling.

A difficulty with these calculations is that future school enrollments among the set of people not completing the extra year of schooling may provide a poor guide to what would have happened to the person who finished the extra year of schooling had they not done so. Consider a 17-year-old with 11 years of schooling who completes a 12th year of schooling and graduates from high school during the following year. To determine the value of that extra year of education, Jorgenson and Fraumeni would compare the projected future earnings of the 18-year-old with 12 years of schooling to the projected future earnings of an 18-year-old with 11 years of schooling. The problem is that an 18-year-old with just 11 years of schooling is someone who has fallen off track educationally. The probability of that individual continuing with their education is low. Because the people who continue on in school almost certainly differ in their ability, motivation and other characteristics from those who drop out, however, the experiences of the dropout group may not provide a good indication of what would have happened to the person completing their 12th year of school had they failed to graduate at age 18 (Christian 2010). An alternative counterfactual for what would have happened had the 18 year-old not completed year 12 might be that the probability of their doing so is the same as for a 17 year old with 11 years of schooling—a person who is still on track educationally.

Christian (2010) shows that assumptions about future enrollments can have a very large effect on the estimated returns to formal education. In one illustration, under the standard Jorgenson and Fraumeni counterfactual, the market component of gross investment in education had a value of $16 trillion in 2005. Under the alternative assumption that, had a person who acquired a year of education not done so, the probability of their doing so subsequently would have been the same as for a person with the same initial education who is a year younger, the market component of gross investment in education in 2005 is just $3.1 trillion.[6]

A second challenge for the income-based approach is how best to consider the benefits of human capital for individuals not engaged in market work, but who engage in enjoyable or productive non-market activities. Jorgenson and Fraumeni decide to value both market and nonmarket time. They reason that individuals will choose to work up to the point where the marginal return to working just equals the marginal value of time at home. They assume 10 hours per day devoted to personal maintenance activities and (at younger ages) 1,300 hours per year devoted to education by people who are in school. Then, they treat the value of non-market time as equal to the (actual or imputed) wage rate less the marginal tax rate on labor income.

The decision to count both the market and the nonmarket returns to education has a very large effect on income-based estimates. In the original Jorgenson and Fraumeni (1992b) analyses, the value of investment in education including both market and nonmarket returns is 2.3 to 3.2 times as large as the market component on its own, depending on the year. Similarly, in evaluating the returns to investment in education net of aging, Christian (2014) estimates total values that are roughly double the values based on market returns alone.

[6] These calculations assume an annual growth rate in earnings of 2 percent and a discount rate of 4 percent. For his own estimates, Christian (2010) chooses to focus on the net return to education—comparing the projected earnings of a person age $a+1$ and $e+1$ years of schooling to those of a person of age a with e years of schooling—rather than the gross returns. As can be seen in Figure 5 of the working paper version of his paper (Christian 2009), however, at the discount rates he assumes, this yields results very similar to calculating gross returns under the second of the counterfactual assumptions just discussed.

Even counting only the market returns to education, estimates of the value of investments in education are very large compared to investments in other assets. Jorgenson and Fraumeni (1992b), for example, report that, in 1986, formal education raised the present value of the market returns to education by about $1.6 trillion dollars (in 1986 dollars). This is close to double total gross private domestic investment for the same year, based on data from the US Bureau of Economic Analysis. Including nonmarket returns, the Jorgenson and Fraumeni estimate of the value of investment in educational capital in 1986 was roughly 4.5 times as large as the official estimates for gross private domestic investment. Studies for other countries have found similar or larger multiples. Liu (2014) reports that, in a set of 10 OECD countries as of 2006, ratios of the value of the stock of human capital estimated based just on the market returns to the value of the stock of physical capital ranged from 3.7 in the Netherlands to 7.0 in the United Kingdom. Due both to discomfort with the even larger values obtained when nonmarket returns are included and, more importantly, the additional data and assumptions required to value nonmarket returns,, applications of the Jorgenson and Fraumeni income-based approach often have focused only on the market returns.

A third challenge for the income-based approach is that, among those of a given age and sex, all differences in future earnings between people with different levels of education are attributed to the differences in their educational attainment. Some of these differences may in fact be a result of returns to other types of human capital investment. For example, the higher earnings of more educated people may reflect not only returns to education but also returns to larger early childhood investments (Björklund and Salvanes 2011).

Returns from on-the-job training also might bias estimates of the value of investments in formal education. After completing their schooling, highly educated workers are more likely to participate in on-the-job training than are less educated workers (for example, Bureau of Labor Statistics 1996; Eurostat 2021). Moreover, educated workers experience steeper growth in earnings with experience. It is not obvious, however, whether this leads to bias in estimates of the value of education. Conceptually, a worker entering the labor market will choose among career paths with different amounts of on-the-job training and different wage profiles. In market equilibrium, all of the career paths available to a worker should offer the same expected present value of earnings (Becker 1964). If workers apply the same discount rate in evaluating present and future income that the analyst uses when constructing income-based estimates of investment in educational capital, then the analyst's calculations should not be affected by whether educated people also invest more in on-the-job training. If, however, workers apply a higher discount rate in deciding whether to make on-the-job training investments, then when more-educated workers nonetheless choose more training, the estimated value of acquiring additional education will be upward biased. O'Mahony and Stevens (2009) is one paper that has recognized the potential confounding of returns to education and returns to experience.

Empirical Measures of Human Capital Investments and Stocks

In this empirical discussion, we begin with a short review of cross-country evidence on human capital, then turn to a comparison of estimates based on the cost and income approaches. As already discussed, the cost approach to measuring the value of investments in education is based on the costs of producing formal education; the income approach attempts to value the resulting output. Similar to the way in which the income-based and expenditure-based estimates of Gross Domestic Product embedded in the double-entry bookkeeping of the national income and product accounts provide a check on one another, it would be reassuring if the estimates of human capital investment based on the cost and income approaches were of similar magnitude. In practice, estimates of the value of investments in human capital based on the income approach have been far larger than estimates based on the cost approach. We discuss why the two approaches might produce such different answers and whether there is a way to reconcile them.

Cross-country evidence

Investigating how differences in human capital contribute to cross-country differences in economic growth requires a measure produced in a comparable fashion across countries and over time. Candidates in the literature include various indicator measures of human capital—for example, measures of years of schooling like those in the Barro-Lee dataset (Barro and Lee 2021), the World Bank Human Capital Index (HCI) (World Bank 2020) and the World Economic Forum Global Human Capital Index (GHCI) (Samans et al. 2017). Perhaps surprisingly, though there would be no conceptual barrier to producing a measure of human capital investment suitable for cross-country comparisons based on the cost approach, no such measure appears to exist. Both the World Bank and the United Nations have produced income-based measures of human capital investment.

The income-based measure of human capital developed by the World Bank—defined as the present value of current and future market incomes for the population age 15-64—uses the approach developed by Jorgenson and Fraumeni to assign present values to individuals in different age/sex/education cells. The Bank's 2018 Changing Wealth of Nations (CWON) report contains estimates for 2014 for 141 countries developed using information from its extensive database of household surveys; market exchange rates were used to convert the country-specific numbers to US dollars (World Bank 2018).[7] Using a somewhat different approach based on Klenow and Rodriguez-Clare (1997) and Arrow et al. (2012), the United Nations Environment Programme (UNEP) has produced alternative income-based measures of the stock of human capital. Its 2018 Inclusive Wealth Report (IWR) reports on estimates for 2014 for 140 countries.[8] The UNEP IWR estimates value the human capital possessed by adults who are past the age normally required to complete their reported level of education based on an assumed rate of return to schooling. Although conceptually similar, the UNEP IWR estimates differ from the World Bank CWON estimates in several ways. First, in these estimates, each year of education raises the human capital that a person possesses by a fixed percentage amount. Second, the calculations make no distinctions based on the likelihood that a person will work for pay, so that the estimates capture both market and nonmarket returns to education. Third, the country-specific human capital values were converted to US dollars using purchasing power parities rather than market exchange rates (Managi and Kumar 2018).

[7] These estimates built on an earlier initiative undertaken at the Organisation for Economic Cooperation and Development (Liu 2011).

[8] Barbara Fraumeni kindly shared these data with us.

Although these different measures have distinct underpinnings, one can ask whether they vary similarly across countries and over time. In Table 2, we report cross-country correlations for the five measures mentioned in the preceding paragraphs. [9] In addition to the two income-based measures for which we have 2014 data, the calculations use Barro-Lee data for 2015, HCI data for 2017 and GHCI data for 2017; the years were chosen to be as close together as possible given the available information.[10] To scale the income-based measures, we use the natural logarithm rather than the level of the per capita value of countries' human capital, which is similar to using percentage differences rather than absolute differences across countries in the calculations. The Table 2 correlations are Pearson correlations that represent the covariances between pairs of measures across countries, standardized by dividing by the product of the standard deviations of the two series, so the resulting number always lies between -1 and 1.

All five of the measures we examine are positively correlated with each of the others. The most closely related are the three indicator measures (the Barro-Lee measure of years of schooling, the World Bank HCI and the World Economic Forum GHCI); each of the pairwise correlations involving these measures lies above 0.85. The UNEP IWR ln(per capita value of human capital) measure is less highly correlated with the indicator measures than the World Bank CWON ln(per capita value of human capital) measure. Perhaps surprisingly given their conceptual similarity, the correlation between the two ln(per capita value of human capital) measures is not especially high but rather lies in the middle of the pack.

Table 2: Correlations Across Countries for Selected Human Capital Measures

Measure	Indicator: Barro-Lee years of schooling	Indicator: World Bank HCI	Indicator: World Economic Forum GHCI	Income-based: Ln(World Bank CWON)	Income-based: Ln(UNEP IWR)
Indicator: Barro-Lee years of schooling	1.000	--	--	--	--
	(146)				
Indicator: World Bank HCI	0.872	1.000	--	--	--
	(132)	(157)			
Indicator: World Economic Forum GHCI	0.852	0.892	1.000	--	--
	(124)	(126)	(130)		
Income-based: Ln(World Bank CWON)	0.796	0.850	0.788	1.000	--
	(122)	(132)	(117)	(141)	
Income-based: Ln(UNEP IWR)	0.691	0.774	0.656	0.814	1.000
	(138)	(130)	(123)	(122)	(139)

Source: Authors' calculations.
Note: HCI=Human Capital Index. GHCI=Global Human Capital Index.CWON=Changing Wealth of Nations. UNEP=United Nations Environment Programme. IWR=Inclusive Wealth Report. Barro-Lee data for 2015; World Bank HCI data and World Economic Forum GHCI data for 2017; World Bank CWON and UNEP IWR data for 2014. Income-based measures of human capital are ln(per capita value). Numbers in parentheses are counts of countries for which each pair of measurs available. Implausible UNEP IWR value for Slovakia dropped.

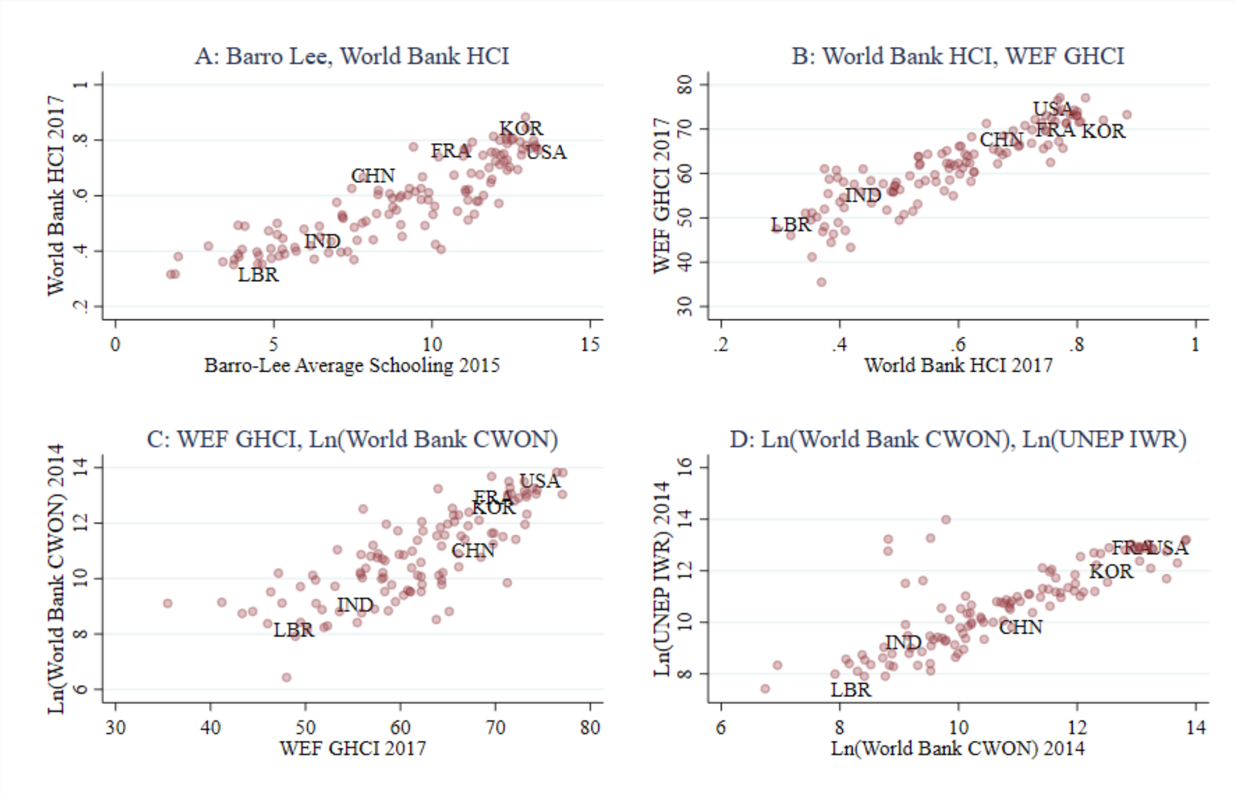
[9] Liu and Fraumeni (2020) report correlations similar to those reported here for a somewhat different set of measures.
[10] HCI data for slightly fewer countries are available for 2017 (157 countries) than for 2020 (174 countries). We drop the estimated per-capita value of human capital in Slovakia in the IWR data because it is prima facie implausible (nearly 20 times as large as the estimated US value), leaving us with IWR data for 139 countries.

Figure 1 contains scatterplots of selected pairs of measures. Panel A plots the Barro-Lee measure against the HCI; Panel B, the HCI against the GHCI; Panel C, the GHCI against the World Bank CWON ln(per capita value of human capital) measure; and Panel D, the World Bank CWON ln(per capita value of human capital) measure against the conceptually similar UNEP IWR measure. In each pairing displayed, countries with high values on one measure tend to have high values on the other. It also is clear, though, that the relationships between the two pairs of indicator variables displayed in Panels A and B are stronger than the relationships involving one or both of the ln(per capita value of human capital) measures displayed in Panels C and D. Even after removing the UNEP IWR value for Slovakia as implausible on its face, there are six dots in Panel D for which the UNEP IWR values lie well above the level expected based on the World Bank CWON measure. These dots represent Cote D'Ivoire, Kyrgyzstan, Moldova, Tanzania, Turkey, and Vietnam. The UNEP IWR numbers place the per capita value of these countries' human capital well above that in other developing economics, at or above the levels for the US and other developed nations. These anomalous results suggest that, at least for 2014, the World Bank CWON measures should be preferred to the UNEP IWR measures.

Estimates of human capital: Investments and stocks

Applying the tools of growth accounting to human capital requires monetary measures of human capital constructed using methods more consistent with those used in the existing national income and product accounts—the cost-based and income-based measures discussed above. Discussing his cost-based capital stock estimates, Kendrick (1976, p. 19) states: "Our net capital estimates in current prices … approximate market values, assuming reasonably good foresight by the businessmen [sic] who made the investment decisions." In other words, he argues, the amount that an informed individual making an asset purchase would spend should be just the anticipated present value of the returns to that asset. To the extent that similar reasoning applies to human capital, the cost and income approaches to estimating investments in human capital should give similar answers. In practice, where both are available, estimates of investment in education—and other types of human capital—using the income method based on the valuation of future returns have been much larger than corresponding estimates based on the costs of the resources devoted to these investments.

Figure 1: Relationships between Selected Pairs of Human Capital Measures



Source: Authors' calculations.
Note: HCI=Human Capital Index. GHCI=Global Human Capital Index. CWON=Changing Wealth of Nations. UNEP=United Nations Environment Programme. IWR=Inclusive Wealth Report. Barro-Lee data for 2015; World Bank HCI data and World Economic Forum GHCI data for 2017; World Bank CWON and UNEP IWR data for 2014. Income-based measures of human capital are ln(per capita value). Implausible UNEP IWR value for Slovakia dropped.

Consider the relative magnitudes of the cost-based estimates of the value of investment in education and training reported by Kendrick (1976) and the income-based estimates of investment in formal education reported by Jorgenson and Fraumeni (1992b). The estimates of human capital from these two sources, which overlap for the years from 1947 to 1969, are dated but remain the most authoritative available for comparison purposes. Kendrick's cost-based estimates are in some ways more inclusive than the Jorgenson-Fraumeni estimates. In addition to direct spending on schools and an estimate of the opportunity cost of student time, Kendrick's estimates include spending on libraries, religious education and employee training, as well as a portion of spending on radio, television, books and other items that are treated as having educational value. The Jorgenson and Fraumeni estimates refer strictly to the incremental returns to additional years of formal education. Despite their more restricted scope, the Jorgenson and Fraumeni estimates are 6 to 9½ times as large as the Kendrick estimates, depending on the year. Even if one looks only at the market returns to education in constructing the income-based estimates, the Jorgenson and Fraumeni results imply values for the investment in education that are 2 to 3 ½ times as large as those reported by Kendrick.[11]

In calculations using Canadian data, Canada, Gu and Wong (2015) report estimates of the value of investments in formal education on both a cost and an income basis for the period from 1976 through 2005. The differences they find between income-based estimates of market returns to formal education and the corresponding cost estimates are even more striking, with the former roughly 6 to 14 times as large as the latter, depending on the year (see their Figure 5).

Estimates of the total stock of human capital using cost-based versus income-based methodologies—including both education capital and human capital acquired through other types of investments—are even more different.[12] To estimate the value of the stock of human capital, Kendrick (1976) takes into account the costs of rearing individuals to the point at which they can be productive, including the value of the time their parents spent caring for them as young children, together with the costs of food, clothing, shelter and so on. He combines these costs with spending on health, education, and training, then applies the perpetual inventory method to the spending series to obtain stock estimates. In the alternate approach, income based-based estimates reported by Jorgenson and Fraumeni (1992b) value the future flow of income to the current population by age, sex and level of education. In each of the years for which the estimates can be compared (1948 through 1969), the Jorgenson and Fraumeni estimates of the value of the total stock of human capital are roughly 18 times as large as the Kendrick estimates. Even if the income-based estimates are adjusted to consider only the contribution of market earnings to the value of the stock of human capital, the Jorgenson and Fraumeni income-based estimates are still 5 or 6 times as large as Kendrick's cost-based estimates.[13]

Seeking a reconciliation

Why do income-based estimates of human capital from income-based approaches tend to dwarf their cost-based counterparts? Our sense is that the divergence is more likely to be the result of overstatements by the income approach than understatements from the cost approach.

It is possible that past efforts using the cost-based approach have understated the full cost of education, but it seems unlikely that any understatement could be large enough to make a significant dent in the very large observed discrepancies in the two sets of estimates.

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[11] The cited estimates refer to current-dollar cost-based estimates of the value of investment in education from table B–2 of Kendrick (1976); current dollar income-based estimates from table 8.6 of Jorgenson and Fraumeni (1992b); and estimates of the share of the value of investment in education accounted for by market income from table 8.11 of Jorgenson and Fraumeni (1992b).

[12] We can't compare estimates of the stock of education capital based on the two approaches because that isn't separately identified in the Jorgenson and Fraumeni numbers.

[13] The cited estimates refer to current-dollar cost-based estimates of the stock of human capital from table B-20 of Kendrick (1976); current-dollar income based estimates from table 8.12 of Jorgenson and Fraumeni (1992b); and estimates of share of the value of the human capital stock accounted for by market income from table 8.16 of Jorgenson and Fraumeni (1992b).

There are, however, several plausible reasons why estimates based on the income approach might overstate the value of investments in education. The income-based approach could: 1) apply an intertemporal discount rate that is too low (or equivalently, an expected growth rate in future earnings that is too high); 2) overestimate the returns to education by understating the counterfactual earnings prospects for those who acquire additional education; 3) exaggerate the returns to education by valuing nonmarket time for educated workers based on their market wage; and 4) confound the returns to education with the returns to other investments in human capital (Abraham 2010).[14]

To explore some of these possible explanations, we have constructed cost-based and income-based estimates of investment in education for the United States covering the period from 2006 through 2020. Our cost-based estimates incorporate all of the direct spending on education by households, nonprofit institutions serving households and governments included in the national income and product accounts. To those costs, we add an estimate of the value of the time that students age 15 and older devote to education. This estimate is based on school enrollment data from the October education supplement to the Current Population Survey (CPS) normalized to match enrollment counts reported by the National Center for Education Statistics (NCES) and earnings data from the Annual Social and Economic Supplement (ASEC) to the CPS. Following the literature, we assume that enrolled students devote 1,300 hours per year to their schooling and value the opportunity cost of that time at the hourly wage of individuals of the same age, sex and completed education level. As a crude correction for the fact that wages are only a portion of total compensation, we multiply this estimate by 1.235, the average ratio of total compensation to wages and salaries in the national income and product accounts over the 2006-2020 period. Finally, we construct a rough estimate of the value of parent time devoted to their children's schooling using data from the American Time Use Survey on the time adults spend helping children with their schooling. To value this time, we use annual average CPS data on median weekly earnings for full-time elementary and middle school teachers, converted to an hourly wage assuming that full-time means 40 hours per week and adjusted upwards by a factor of 1.235 to account for components of compensation other than wages and salaries.

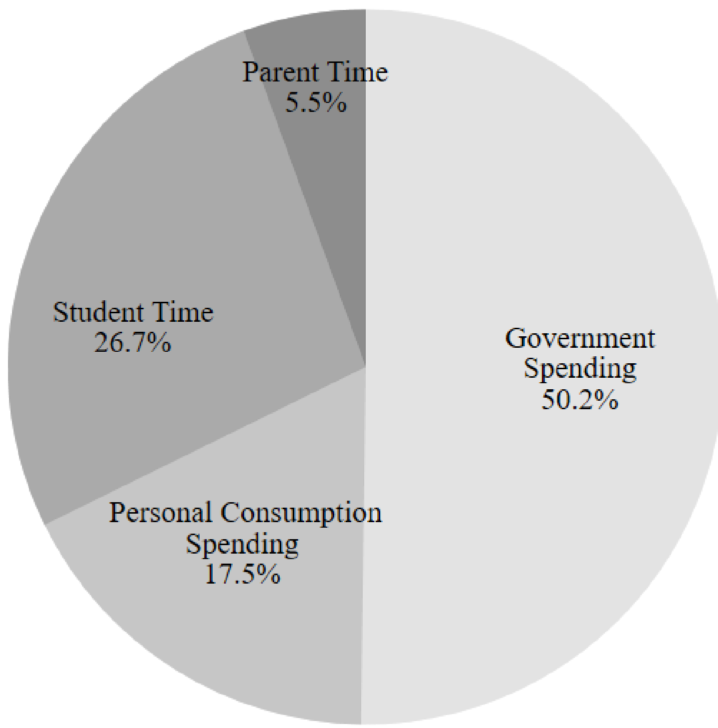
Figure 2 shows the relative importance of the different components of the estimated cost of investments in formal education in 2020; the cost shares for other recent years are similar. Government spending accounts for just over half of estimated costs in 2020 (50.2%). The next largest contributor is the value of student time at 26.7%, with expenditures by households and nonprofit institutions serving households accounting for 17.5% and parent time for 5.5%.

Our income-based estimates generally follow the approach developed by Jorgenson and Fraumeni. Earnings and hours by age, sex and education come from the ASEC. Mortality rates by age and sex come from the National Center for Health Statistics' mortality files. As for the cost-based estimates, the information on school enrollments used for the income-based estimates comes from the October education supplement to the CPS, normalized to match enrollment counts from the NCES. One difference from the original Jorgenson and Fraumeni calculations is

[14] Other reasons to question the income-based estimates include the possibility that earnings reflect factors other than productivity or that relative earnings for different groups of workers might change in the future (Abraham 2010). Even if true, however, it is not clear that either of these would lead to systematic overstatement in the value of investments in education.

that, using a modification to their approach introduced by Christian (2010), we allow for the possibility that individuals older than age 75 have labor earnings. Another difference is that we use pre-tax wages rather than post-tax wages to estimate the returns to education. As a rough adjustment to account for the value of nonwage compensation, we also multiply the estimated returns to formal education based on the ASEC wages by 1.235. Consistent with the original Jorgenson and Fraumeni work, our baseline estimates assume that the relevant counterfactual for individuals who complete an additional year of schooling is that, had they not done so, their probability of returning to school in the future would have been the same as for a person of the same age but one less year of schooling. Income is assumed to grow at 2 percent annually and the temporal discount factor is set to 4 percent. For this analysis, we count only the market returns to education.

Figure 2: Breakout of the Costs of Investment in Formal Education, 2020



Source: Authors' calculations.
Note: Data on personal consumption and government spending on formal education from the National Income and Product Accounts. Estimated value of student and parent time constructed using data from multiple sources as described in the text.

We would like to know whether varying the assumptions underlying our baseline income-based estimates of investment in education can reconcile the cost-based and income-based estimates. Figure 3 displays the results of this exercise.

Panel A, in the upper left, compares the nominal dollar value of the income-based and cost-based estimates of the value of investment in education under our baseline assumptions. Under these assumptions, the estimated gross market return to investment in education using the income approach is roughly 11 to 15 times the value of the same investment based on the costs of education, depending on the year. These are proportionally larger differences than obtained by comparing the market income-based values reported by Jorgenson and Fraumeni (1992b) to Kendrick's (1976) cost-based estimates for the years 1947 through 1969. Allowing for earnings past age 75, using pre-tax wages rather than post-tax wages and adjusting the data to account for the fact that wages and salaries are only a portion of total compensation makes our ratios somewhat larger. The rise in female labor force participation since 1970, and the accompanying shift from nonmarket to market activity (Fraumeni and Christian 2019), also may help to explain why our ratio is larger. Our numbers are in the same ballpark as the recent estimates for Canada reported by Gu and Wong (2015).

Panel B, in the upper right, modifies our discount rate assumption. As an alternative to assuming an intertemporal discount rate of 4 percent, we assume an intertemporal discount rate of 10 percent. This is admittedly a much higher discount rate than is typical in the literature, but could perhaps be appropriate for the evaluations made by myopic or risk averse individuals regarding an investment they cannot diversify.[15]

Panel C, in the lower left, modifies our enrollment counterfactual for the income-based estimates concerning the future path of enrollments for someone who misses a year of school. For our alternative counterfactual regarding future education, we assume the same future enrollment probabilities as for someone a year younger with one less year of education, as opposed to the future enrollment probabilities for someone the same age with one less year of education. Because the probability of continuing in school is much higher for people who are on track educationally than for people who have fallen behind, the baseline assumption implies a big difference in expected future earnings for people the same age whose current educational attainment differs by a year. At least in part, however, the differences in future enrollment probabilities are likely to be due to differences in the characteristics of the people who select into staying in school versus dropping out. Our alternative counterfactual assumes, in essence, that someone who fails to complete a year of schooling gets a do-over. Under this alternative counterfactual, the value of completing an extra year of schooling is considerably smaller since it has less effect on a person's future educational attainment.

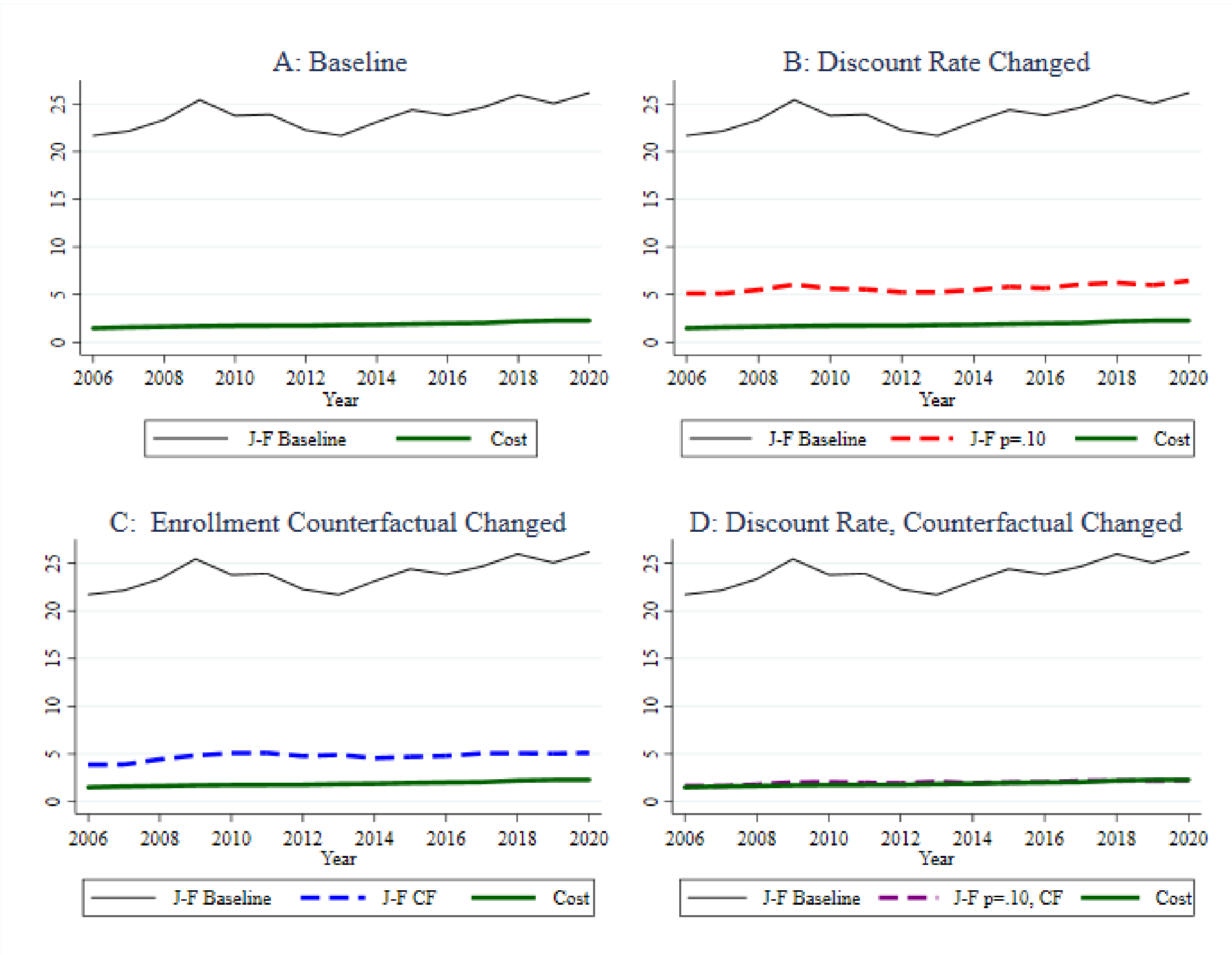
Panel D, in the bottom right, plots gross investment in education under the income-based approach using both our alternative assumption about the discount rate and our modified counterfactual assumption about probabilities of enrollment for someone who misses a year of school. Changing either our assumption about the discount rate or our assumption about future enrollment probabilities, as is done in Panels B and C, reduces the size of the gap, but the income-based estimates are still 2 ½ to 3 ½ times as large as the cost-based estimates. Making both changes simultaneously effectively reconciles the average levels of investment estimated using the income-based and cost-based approaches.

Of course, this illustrative set of calculations does not prove that our alternative assumptions are "correct" in any sense. Our calculations do show, however, that methodological

[15] We do not vary our assumption about the growth rate of future earnings, but lowering the assumed growth rate for earnings by one percentage point would be essentially equivalent to raising the assumed temporal discount rate by one percentage point.

assumptions—some fairly obvious like the discount rate, others more subtle like how to model the wage path of those who have fallen a year behind the conventional path in their schooling—can make a large difference in these estimates.

Figure 3: Alternative Estimates of U.S. Investment in Human Capital, 2006-2020



Source: Authors' calculations.
Note: J-F Baseline refers to Jorgenson and Fraumeni estimates based on market returns making their baseline assumption about enrollments and assuming a 2 percent earnings growth rate and 4 percent temporal discount rate. J-F P=.10 changes the assumed temporal discount rate to 10 percent per year. J-F CF changes the assumption about how completing a year of schooling changes future enrollments as described in the text. J-F p=.10, CF makes both changes. Cost refers to our cost based estimates of investment in education. All figures are in dollars of the indicated year.

Topics for Future Research

Our discussion has focused mainly on estimates of the value of investments in formal education produced using the cost and income approaches. Estimates produced using these approaches are appealing in that they are conceptually compatible with the existing national income and product accounts. A considerable agenda for future research on the measurement of human capital remains, and here we highlight some major issues.

One issue we have not addressed is the heterogeneity in formal education. Even among those in a given country who have the same number of years of schooling, the value of human capital may depend a great deal on the specific type of schooling a person received. In some contexts, measuring educational attainment by credentials, rather than years of schooling, may be more meaningful. It also may be important to take account of changes related to the characteristics of the students being educated, such as changes in the prevalence of regular versus special education students or students whose native language is not English (Fraumeni et al. 2009). A related complication for cross-country comparisons is that some countries emphasize formal education in preparing young people for careers, whereas credentials acquired through structured on-the-job training, such as apprenticeship programs, plays a larger role in others (Conrad 1992).

Further, the quality of education—what it means, for example, to have a high school diploma or a college degree—may have changed over time. This heterogeneity might be captured by looking either at inputs or at outputs. For example, some of the inputs plausibly affecting the quality of the education a student receives include class size and teacher qualifications such as degrees earned, whether the teacher has been trained in the subject being taught, and years of teaching experience (Fraumeni et al. 2009, UNECE 2016). Alternatively, output measures like test scores may be a useful proxy for the quality of educational attainment, though the skills measured by available tests capture only some of the skills that are likely to affect a person's labor market outcomes (Heckman, Stixrud and Urzua 2006). Finding adequately reliable and robust ways to account for changes in the quality of education over time and differences in the quality of education across countries would be an important step forward.

Second, there may be a more nuanced way to calculate the nonmarket private returns to education than has been adopted in the literature thus far. In many common tasks of home production, like cleaning the bathroom or doing the laundry, more educated individuals seem unlikely to enjoy a productivity advantage, but they might have an advantage in others, like engaging with children in ways that enhance their human capital. Finding a way to assess the productivity of more versus less educated individuals in various activities would be a difficult but perhaps not impossible task. One possible approach would be to assign values to time devoted to home production of goods and services that could in principle have been purchased from third-party suppliers.

Finally, the income approach to valuing investment in education treats the returns to education as captured fully by the increment to individual earnings. Although this is a useful starting point, there are almost certainly positive spillovers to others in the population. Positive externalities associated with having a more educated population may include such things as a more informed electorate and a lower crime rate (Abraham and Mackie 2005), as well as the possible agglomeration effects made possible by having larger numbers of highly skilled individuals working together (for example, Puga 2010).

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