An Accounting Framework for Human Capital

Authors Justine Mallatt, U.S. Bureau of Economic Analysis[1]

Contact justine.mallatt@bea.gov

Date March 2026

Abstract Human capital is a primary driver of economic growth, yet the United States lacks an official measure in its national accounts. This accounting fails to capture education's full economic significance and contrasts sharply with how other capital assets contribute to GDP. The omission risks skewing investment decisions toward other forms of capital, since their contributions to growth are fully recognized in the accounts while human capital's are not. To address that, this paper proposes and produces an accounting framework that values human capital as an asset and tracks nationwide investment in, and stocks of, human capital over time. The framework applies two methods: a cost-based approach and an income-based approach. Both methods show a substantial increase in GDP after accounting for human capital investment, but the higher value of the income-based approach reveals substantial returns on educational investment, although the return appears to be declining over time. Cost-based investment averaged 10 percent of GDP, while income-based investment ranged from 20 to 30 percent of GDP—comparable to gross investment in all other forms of capital combined. The framework provides a more complete picture of growth, with both counterfactual analysis and observed dynamics during the Great Recession and the COVID–19 pandemic showing that human capital invest-ments can meaningfully alter measured economic fluctuations compared with traditional accounts.

Keywords Human capital, System of National Accounts, national accounts, returns to education

JEL Code E01, I20, H52, I26

[1] I would like to thank Abe Dunn for his invaluable input, as well as Jon Samuels. Thanks to Katharine Abraham, Gang Liu, Dennis Fixler, Calvin Ackley, and Lasanthi Fernando for their comments. Thanks to Mike Christian for answering my questions and for his valuable previous work on this topic. Thank you to Peter Shieh, who updated the cleaning code.

Bureau of Economic Analysis
U.S. DEPARTMENT OF COMMERCE

1. Introduction

Economists have long recognized human capital as a primary driver of economic growth, with its conceptual roots going back to Adam Smith and its development central to modern theories of growth, including those of Lucas et al. (1988), Romer (1989), and Barro and Sala-i Martin (2004). Human capital is the knowledge, skills, competencies, and attributes embodied in individuals that contribute to personal, social, and economic well-being. One can view human capital in time t as a function of years of education, on the job training, innate ability, health, and human capital in the previous period. In 1961, Simon Kuznets called for a broader classification of capital to include investments in education and training, highlighting the role of human capital as central to growth, and accordingly this paper concentrates on the role of formal education.[2]

Despite widespread acknowledgment of its importance, the United States lacks an official measurement of human capital in its national accounts. Current accounting practices treat education spending as consumption during the year it occurs, rather than as investment in a productive asset that generates future returns. This treatment contrasts sharply with how other capital assets are measured and carries important policy implications. While investment in physical capital and intangible capital are reflected directly in gross domestic product (GDP) growth, investments in people—such as education or workforce training—register little to no effect.[3] This imbalance risks tilting investment priorities toward other forms of capital at the expense of human capital, despite the latter's central role in long-run economic growth. The omission of the long-term benefits of human capital investment understates both national wealth and the return on policies that expand education.

Two established approaches provide pathways for measurement, though each presents unique challenges. The cost-based method sums the direct and indirect resources devoted to primary, secondary, and post-secondary and professional education, including student time costs and parental support. Cost-

[2]There is a large literature on human capital, other factors of production and their combined influence on economic development. While other inputs into the generation of human capital include investments in health and training outside of formal education, we lack detailed data sources on these inputs and their role in increasing human capital.

[3]The fixed asset accounts track stocks, investment flows, and depreciation for physical capital (equipment, structures, inventories) and intangible assets (software, research and development), but no comparable framework exists for human capital.

based investments are easier to link to GDP and are based on observed inputs. However, they likely understate long-run value creation, as inputs generate surplus human capital that is above the value of the input. The income-based method, following Jorgenson and Fraumeni (1989), values the incremental gains to expected lifetime earnings from additional years of education. Income-based measures better reflect the full value of investment but rely on estimating unobserved future income, creating greater uncertainty. The quality of the estimation affects the quality of the income-based method and could lead to overestimation.

Similar to the findings of others in the literature, these approaches yield substantially different levels for investment, with income-based measures exceeding cost-based measures by a substantial amount (Abraham and Mallatt (2022); Christian (2010); Kendrick (1974); Jorgenson and Fraumeni (1989, 1991, 1992)). However, consistent with Abraham (2010) and Liu (2015), this paper views this difference as providing valuable information: the difference between cost-based and income-based measurements may reflect the substantial returns to educational investment at the national level, echoing what Abraham (2010) defines as profits to the household sector, and what Liu (2015) conceptualizes as individuals' gross operating surplus generated from their educationally obtained skills. With this view, the difference between the two estimates offers information on expected rate of return for investment in the human capital asset, an idea dating back to Friedman and Kuznets (1945).

This study develops an accounting framework for human capital that applies both approaches to measure human capital investment and stocks for the United States between 1994 and 2023. The framework recasts education as an investment asset and demonstrates how incorporating human capital alters the level and dynamics of GDP. Cost-based investment doubled from about $1.1 trillion in 1994 to $2.2 trillion in 2023 (inflation-adjusted 2017 dollars), averaging 10 percent of GDP. In the base model, income-based investment was larger than cost-based investment—$4.4 to $5.3 trillion annually, or 20—30 percent of GDP—comparable to gross investment in non-human capital already recognized in the accounts. Incorporating cost-based investment raises nominal GDP by about 2.6 percent on average, while income-based measures raise it by nearly 15 percent. The income-based method of measuring the stock of human capital puts it at equal to or more than the value of capital stock.

The accounting framework also proposes a way to understand and reconcile the income-based and cost-based estimates that can be used to calculate a national return on investment in education. I find substantial returns on education of around 17% per year over the study period. These returns are large, and Friedman (1955), Abraham (2010), and Abraham and Mallatt (2022) argue that from an individual's perspective education is a risky asset as it cannot be diversified, justifying a higher return. The results suggest robust returns, though declining, with the internal rate of return falling from 19% in 1997 to 15% in 2021. The decline in returns is consistent with recent studies that show the returns to education have been flattening (Valletta (2018), Bengali et al. (2025), and Bengali et al. (2023)), while costs have risen at a rate above inflation (Cai and Heathcote (2022) and Cooper (2025)). Importantly, one challenge of applying the income-based approach to value this risky asset is the uncertainty involved in using income across the age and education spectrum to predict the future wage paths of individuals. For this reason, I present a range of human capital estimates.

Because traditional GDP excludes investment in human capital, it can obscure the economy's trajectory during downturns; the framework addresses this gap by incorporating educational investment, revealing growth dynamics that critically depend on young adult enrollment rates. To demonstrate the importance of these dynamics, I consider how the inclusion of human capital would have affected GDP growth during the Great Recession period between 2007 and 2012, as well as the COVID–19 economic downturn and recovery between 2020 and 2023. During the Great Recession, enrollment rose relative to a 2000–2006 baseline (Goodman and Winkelmann (2025)), causing a rise in investment in human capital, which cushioned or mitigated the downturn in GDP. However, during the COVID downturn and post-COVID recovery years, enrollment rates fell,[4] magnifying the economic contraction. These two contrasting periods illustrate that accounting for education links present enrollment to future productive capacity, which can affect GDP in a pro-cyclical or counter-cyclical fashion depending on enrollment trends or responses.

Beyond cyclical dynamics, the proposed framework offers a broader framework for analyzing education as an investment in national wealth. Because upfront investment in education yields future gains in lifetime earnings, incorporating human capital into GDP can yield insights not visible in traditional measures. To illustrate, I posit an experimental case where five percent of unenrolled high school graduate males enroll in a 2-year program (such as an associate's degree or vocational degree program), and assess

[4] College enrollment rates fell between 2010 and 2023 in National Center for Education Statistics (NCES) and Current Population Survey (CPS) data. https://nces.ed.gov/programs/coe/indicator/cha/undergrad-enrollment. Also see Salam (2024). Schanzenbach and Turner (2022) attribute some of the COVID-19 fall in male enrollment in community college to a falling supply of Assembly, Repair and Maintenance coursework.

the impact on GDP. I compare two accounting treatments; a traditional GDP case where additional schooling raises short-term spending but causes forgone wages, and a framework where GDP contains human capital investment and values the effect of such a program based on its incremental impact on lifetime earnings. Findings show that the additional male enrollment in 2-year programs results in a net decrease in traditional GDP but $137 billion in net gains when valuing the investment based on its impact on lifetime earnings. This example underscores the value of an accounting framework like the one proposed for policy analysis, since without a lifetime-earnings framework, policies may appear costly today while overlooking long-term benefits.

This study contributes to the growing literature on incorporating human capital as an investment asset into national accounts (Kendrick (1974); Jorgenson and Fraumeni (1989, 1991, 1992); Christian (2010, 2014, 2017); Fraumeni et al. (2017); Abraham and Mallatt (2022)). The paper provides four main contributions. First, building upon ideas in Abraham (2010), Abraham and Mallatt (2022), and Liu (2015), this paper reframes the difference in the income-based and cost-based estimates as private returns to investment in education, which offers new insights regarding returns and trends in this sector, connecting back to some of the earliest work in this literature (Friedman and Kuznets (1945)) as well as recent work on the flattening of the college premium. A second contribution of this study is that it extends the Bureau of Economic Analysis' (BEA) human capital accounting work (Abraham and Mallatt (2022); Fraumeni et al. (2017); Christian (2017, 2014, 2010)) by updating estimates through 2023, capturing the COVID-19 economic downturn and recovery period. A third contribution is that it shows, through an examination of the Great Recession and COVID-19, that human capital investment can either cushion or exacerbate economic downturns depending on enrollment responses. Finally, this paper demonstrates the potential usefulness of this account as a tool for policy analysis by conducting the first counterfactual exercise of how enrollment scenarios affect GDP growth when human capital is treated as an asset.

While this paper demonstrates the value of an accounting framework for human capital, several extensions could enhance its usefulness. The analysis treats years of schooling as the primary input, but disaggregating by field of study and degree type (e.g., technical, vocational, liberal arts) would better capture heterogeneity in returns. Closer integration with the core national accounts, along the lines proposed in Fraumeni et al. (2017), would yield a more complete view of human capital's role in the economy. Developing accounts at finer geographic resolution (e.g., state) would enable granular assessment of regional dynamics and inform state and local decision-making. Finally, the estimates from this framework could provide inputs for estimation of neoclassical growth theory models that incorporate human capital.

The remainder of this paper proceeds as follows. Section 2 reviews prior work and the two main approaches to valuing human capital in monetary terms. Section 3 describes the data used for both the cost-based and income-based measures. Section 4 presents the methodology for each approach, the integration of human capital into GDP, and the return on investment framework. Section 5 reports results, including time trends, GDP impacts, and comparisons to other forms of capital. Section 6 concludes with policy implications and areas for future research.

2. Background

Accounting for education and training as investment into the generation of a human capital asset class has generated attention in recent decades. Viewing productive human capacity as an asset has roots in early economics, and was more formally expanded upon in the 1960s and 1970s (Schultz (1962); Becker (1964); Mincer (1974)). After this formalization in growth models, researchers developed measurement methods for cross-country comparisons and to value investment in (i.e. education) and stocks of human capital over time in monetary accounting frameworks.

The System of National Accounts in the United States has historically counted expenditure toward the development of intangible capital—education, training, health, labor mobility, and previously research and development—as consumption expenditure for the household, business, and governmental sectors of the economy. The treatment of educational expenditure as consumption rather than investment is at odds with the intertemporal nature of its benefits. Similarly, BEA reclassified spending on other intangible capital—software, research and development—from consumption to investment (Aizcorbe et al. (2009); Landefeld and Fraumeni (2001); Okubo et al. (2006); Moylan (2001); Moylan and Okubo (2020)). Corrado et al. (2009) demonstrate that such intangible capital has made significant contributions to measured productive capital and economic growth. The inclusion of human capital in a similar framework would align with these precedents, extend the boundary of investment within GDP, and provide a more accurate picture of the economy's productive capacity.

There are two approaches to measuring human capital in monetary terms: the income-based and cost-based approaches (Abraham and Mallatt (2022)).[5] The cost-based method adds up the input costs to generating human capital, mainly covering education expenditures. These direct costs may be supplemented with measures of time costs, health care spending, other training, or extracurricular enrichment. There are relatively few studies on the cost-based method. Kendrick (1974) and Eisner (1978, 1985, 1989) developed national accounting methods that incorporated spending on human-capital generating consumption (education, health, job training, child rearing, and mobility). Recently, Gu and Wong (2015) developed cost-based estimates of human capital investment for Canada, and Abraham and Mallatt (2022) form similar estimates for the United States.[6]

The income-based approach values human capital based on its economic returns. Drawing on the analogy to physical capital, Jorgenson and Fraumeni (1989, 1991, 1992) conceptualized the stock of human capital as the present value of the stream of future earnings for the current population. Each additional year of education raises expected future wages, and the incremental increase in lifetime earnings associated with this attainment constitutes an investment in human capital. Studies applying the income-based method include Christian (2010, 2014, 2017); Abraham and Mallatt (2022) for the United States, Liu and Greaker (2009) for Norway, and Liu (2014) in a more aggregate multinational framework.

This work builds upon frameworks from UNECE (Brathaug et al., 2020), Liu (2015), Abraham and Mallatt (2022), and both Jorgenson and Fraumeni (1989, 1991, 1992) and Kendrick (1974) methodologies to develop a consistent human capital accounting framework. This study extends previous BEA research (Christian (2010, 2014, 2017); Abraham and Mallatt (2022); Fraumeni et al. (2017); Fraumeni and Christian (2020)) by updating human capital estimates through 2023, adding coverage of the post-Great Recession recovery, the COVID–19 crisis, and subsequent years.[7]

[5] Other approaches exist but fall outside the scope of this paper. Indicator-based measures track non-monetary proxies such as years of schooling, test scores, and literacy rates (Barro and Lee (1993, 2001, 2013)), while composite indices such as the World Bank's Human Capital Index (Corral et al. (2021)) or the World Economic Forum's Global Human Capital Index (Samans et al. (2017)) aggregate multiple dimensions of education and health. These approaches facilitate cross-country comparisons but cannot be directly integrated into the monetary structure of the national accounts.

[6] Kokkinen (2011) uses the cost-based method to calculate Finland's human capital.

[7] International organizations have also developed guides and recommendations for constructing human capital satellite accounts. The 2005 National Research Council volume Beyond the Market recommended measuring educational inputs and outputs separately, assigning marginal valuations where possible, and integrating human capital into satellite accounts

3. Data

Data requirements for the cost-based method include direct measures of educational spending and indirect time costs of educational attainment. Table 1 details a list of data requirements and sources. Direct costs include education spending by households and net nonprofit institutions serving households (NPISH) output of education services to households, which are available in BEA's Personal Consumption Expenditure (PCE) Accounts. Government spending on education is from the Government Current Receipts and Expenditures section of BEA's National Income and Product Accounts. Indirect costs include student time costs, which are a combination of enrollment rates and student population from the October Current Population Survey (CPS), and wages of similar students from the CPS Annual Social and Economic Supplement (ASEC). Parent time costs are calculated by multiplying the reported time spent on children's education from the American Time Use Survey (ATUS), valued by the hourly wage of elementary school teachers, following Abraham and Mallatt (2022).

The income-based Jorgenson-Fraumeni model requires estimates of student enrollment rates and population by year of education, which are obtained from the CPS October education supplement. The model also requires wage rates and hours worked, pulled from the CPS March ASEC supplement. Wages are adjusted for federal and state taxes using the TAXSIM model from the National Bureau of Economic Research (NBER).[8] Survival rates by age and sex are obtained through Social Security Administration tables. Aggregate U.S. population counts are obtained from the U.S. Census Bureau. Student enrollment counts are weighted using National Center for Education Statistics (NCES) data. I also use estimates of gross investment, depreciation, stock, and net investment in physical and other intangible capital from BEA's Fixed Asset Accounts. True birth counts and death counts are from the National Vital Statistics System compiled by Center for Disease Control and Prevention (CDC).

Accurately measuring wages by year, sex, age, and education level hinges on the quality of the CPS ASEC data. Recent studies have called into question the CPS reporting accuracy in taxes, wages, and

(Abraham and Mackie (2006); Mackie and Abraham (2005)). The UNECE's Compilation Guide for a Satellite Account on Education and Training (Brathaug et al 2020) proposed a comprehensive framework that includes input-output tables for education, though data constraints often limit the feasibility of full implementation.

[8]Earnings are also adjusted by a factor of 1.235 to reflect additional benefits from employment, following Abraham and Mallatt (2022).

hours worked (Burkhauser et al., 2012; Bee et al., 2022; Borjas and Hamermesh, 2024). Future research may benefit from re-running the income-based method using alternate wage data.

For both cost- and income-based methods, I use the aggregate PCE deflator to adjust nominal estimates into real terms.

4. Methods

4.1. Cost-Based Method

The cost-based method sums the direct and indirect costs of education and classifies spending as investment. Direct costs include household ($HHSpendEd_t$), government ($GovSpendEd_t$) and net NPISH expenditures on education (gross NPISH spending on education services minus NPISH sales of education services to the household sector, $GrossNPISHEd_t - NPISHSalesEd_t$), as well as the reclassified intermediate expenditures by private firms on educational services ($IntermediateEd_t$). Indirect costs are made up of the value of students' forgone earnings during school enrollment ($StudentTime_t$) and the value of parental time dedicated to supporting children's education ($ParentTime_t$).

$$\begin{aligned} CostInv_t = {} & HHSpendEd_t + GovSpendEd_t + GrossNPISHEd_t \\ & - NPISHSalesEd_t + IntermediateEd_t \\ & + StudentTime_t + ParentTime_t \end{aligned}$$

One can view the cost-based approach as offering a lower bound on the calculation of human capital investment. At minimum, one should expect individuals not to lose money by investing in human capital, so the outcome value of lifetime earnings due to human capital should be greater than the cost to acquire it.

Kendrick (1974) proposed constructing stocks from the cost-based estimates of investment using the perpetual inventory method. This method calculates year *t's* stock of human capital based on last year's stock ($CostStock_{t-1}$), this year's gross investment in the form of education spending ($CostInv_t$), and a depreciation rate (δ).

$$CostStock_t = (1 - \delta) * CostStock_{t-1} + CostInv_t$$

Gross investment in education under the cost-based approach is the total of direct and indirect costs, as described above. Measuring the stock of human capital requires a depreciation rate, which reflects the loss of skills due to lack of use, aging, or obsolescence. Following Hulten and Wykoff (1980), the depreciation rate (δ) is derived from the average service life of a cohort (T_A) and a declining-balance rate (R).[9]

$$\delta = \frac{R}{T_A}$$

Baldwin et al. (2007) report econometric estimates for R between 2 and 3. This study applies lower and upper bounds for the average life of a cohort at 40 and 45 years, combined with the range of 2 to 3 for R. These values yield a lower-bound depreciation rate of 0.044,[10] an upper bound of 0.075,[11] and a midpoint of 0.06. This range of depreciation rates is more gradual than depreciation rates for R&D (Corrado et al. (2009); Fraumeni and Okubo (2005)) which range from 10% to 20%.

To calculate initial stock, I combine a strong set of steady state assumptions with the perpetual inventory method. I assume that in a steady state, both capital and investment are growing at a constant rate g, and the ratio of investment to capital stock was stable :

$$K_t = K_{t-1} * (1 + g)$$
$$I_t = I_{t-1} * (1 + g)$$

This is admittedly a strong assumption, but it's useful in setting an initial capital stock. Following the perpetual inventory method:

$$K_t = K_{t-1} * (1 - \delta) + I_t$$

Combining the equations, the initial capital stock is :

$$K_0 = \frac{I_1}{(g + \delta)}$$

[9] This type of declining rate may fit the depreciation path of traditional capital types but may not be right for the consideration of how human skills deteriorate or become obsolete.

[10] $2/45 = 0.044$

[11] $3/40 = 0.075$

The growth rate g is taken as the average real growth rate of cost-based investment between 1994 and 2023, which is 2.6 percent. I calculate the human capital stock using real cost investment, the initial stock estimate, the perpetual inventory framework, and the three different depreciation rates to provide lower, medium, and upper estimates for the stock of human capital.

There are several issues with this approach. Aggregating annual gross spending across time using this method requires strong assumptions about the depreciation rate of human capital and an initial value of the cost-based human capital stock. Previously used methods used to calculate depreciation of human capital over time overestimate depreciation rates. Kendrick (1974) used a double declining balance method to depreciate human capital, following how physical capital was treated. Depreciation methods used in Kendrick (1974); Eisner (1978); Hulten and Wykoff (1980) assign depreciation models that cause human capital to depreciate quickly over the career, which contradicts empirical evidence demonstrating that human capital appreciates over most of a career, declining only later in life (Graham and Webb (1979); Mincer (1958, 1974)). My sense is that workers undergo additional, unmeasured investment in human capital as they generate on-the-job experience and become more productive during their careers. Firms may train workers to increase future productivity (Becker (1962)), and some of the training may impart firm-specific skills or more general skills that workers could use in their future careers elsewhere (Loewenstein and Spletzer, 1999). Alternatively, firms can better organize labor and capital over time from learning by doing Arrow (1962), or the returns to workers' experience. In addition, workers can accumulate additional skills outside of formal education by using tools like the internet and AI. These additional experience and training effects are difficult to value for the cost-based approach but should be reflected in the wages in the income-based method.

Additionally, using gross spending on education underestimates education's ability as an input to increase the output value of human capital, as measured by the return to lifetime earnings. Cost-based flows into the generation of human capital can be viewed as inputs in generating human-capital augmented labor, and the cost of these inputs is not directly related to the value that is eventually produced by human capital, which is more accurately captured by wages (Gu and Macdonald (2016); Abraham (2010)). The excess return to educational investment is a profit or gross operating surplus to individuals, which accumulates in the stock of the income-based method but is not included in the cost-based approach. Therefore, aggregating the input costs over time using the perpetual inventory method leads to the under-estimation of the value of the stock of human capital as the method omits profits or gross operating surplus associated with individuals' embodiment of more human capital.

Because past methods of aggregating flows of cost-based investment into cost-based stocks both overestimate depreciation and underestimate the outcome value of human capital, the current cost-based approach generates estimates that are very low and incomparable with income-based estimates of the stock of human capital. The issues with the perpetual inventory method discussed here are not conceptual, as the perpetual inventory method is a good theoretical way to view the accumulation of capital. The issues mentioned above are current practical problems of measuring the initial value, the appreciation, and depreciation of the human capital stock that serve as inputs into the model.

4.2. Income-Based Jorgenson-Fraumeni Model

The income-based method relies on a lifetime earnings framework developed by Jorgenson and Fraumeni (1989, 1991, 1992). Under this method, the stock of human capital in the population is calculated first, and annual investment is subsequently backed out. The human capital stock in this framework is equal to the present value of all future wages for the U.S. population. The investment in human capital due to education can be backed out by adding up how each year's school enrollment impacted future earnings trajectories of students.

The Jorgenson-Fraumeni model uses backward iteration to form expectations of future earnings. The model is implemented by constructing population buckets at the year, sex, age, and years of educational attainment level, denoted as y, s, a, e. The model starts with 80-year-olds, and assumes per capita market human capital ($PCMHC$) is equal to the mean of per capita income for 80+ year-olds of sex s with e years of education during year y.

$$PCMHC_{y,s,80,e} = PCEarnings_{y,s,80,e}$$

Iterating backward to 79-year-olds, the market human capital is equal to the per capita average wages associated with workers age 79, plus the discounted future wages of an 80-year-old with the same sex and education level in the same year. Future expectations for the 79-year-old take into account the probability of surviving to age 80, $1 - DeathRate_{y,s,79}$, as well as the temporal discount rate $(1+r)$ and can include an assumption about wage growth $(1+g)$. I use a discount rate of 4% and a wage growth rate of 2%, following Abraham and Mallatt (2022); Jorgenson and Fraumeni (1989, 1991, 1992).[12] These rates are nominal, and yearly investment estimates are adjusted for inflation with the PCE price deflator. These parameter choices significantly influence the resulting estimates and highlight the importance of context-specific calibration. The model continues backward in age; each age's market human capital is the mean per capita wages associated with the age/sex/education group in the corresponding year y plus the discounted human capital of a person a year older. This applies to ages 79 descending through age 35.

$$PCMHC_{y,s,79,e} = PCEarnings_{y,s,79,e} + (1 - DeathRate_{y,s,a})\frac{(1+g)}{(1+r)}PCMHC_{y,s,80,e}$$

$$PCMHC_{y,s,a,e} = PCEarnings_{y,s,a,e} + (1 - DeathRate_{y,s,a})\frac{(1+g)}{(1+r)}PCMHC_{y,s,a+1,e}$$

$$\forall a \in \{79, ..., 35\}$$

For those age 5 to 34, the model incorporates educational attainment. Individuals age 15 to 34 can have present earnings. Those age 5 to 14 are assumed to have zero earnings. For each age, education level, sex, and year, the per capita market human capital is equal to per capita earnings $PCEarnings_{y,s,a,e}$ plus a weighted average of the discounted market human capital of people a year older with the same level of education ($PCMHC_{y,s,a+1,e}$) and the discounted market human capital of people a year older with one more year of education ($PCMHC_{y,s,a+1,e+1}$). The weights are associated with the probability of getting an extra year of education, equal to the enrollment rate ($erate_{y,s,a,e}$).

$$PCMHC_{y,s,a,e} = PCEarnings_{y,s,a,e} + (1 - DeathRate_{y,s,a})\frac{(1+g)}{(1+r)}((1 - erate_{y,s,a,e}) * PCMHC_{y,s,a+1,e} + erate_{y,s,a,e} * PCMHC_{y,s,a+1,e+1})$$

$$\forall a \in \{34, ..., 5\}$$

Young children age 0 to 4 have per capita human capital that is the discounted future per capita market human capital of children a year older. This group has zero earnings and is not enrolled in formal

[12] The 4% discount rate was originally selected by Jorgenson and Fraumeni (1989, 1991, 1992) to reflect the long-run real rate of return for the private sector. A 2% wage growth rate was chosen to reflect the Harrod-neutral rate of technological change.

education.

$$PCMHC_{y,s,a,e} = (1 - DeathRate_{y,s,a})\frac{(1+g)}{(1+r)}PCMHC_{y,s,a+1,e}$$

$$\forall a \in \{4, ..., 0\}$$

The National Accounts' production boundary excludes domestic and personal services produced for one's own household, but includes goods and services that are transacted in markets. In the spirit of this production boundary, and following much of the recent literature (Liu and Greaker (2009); Liu (2014); Abraham and Mallatt (2022)), I value only market time in my calculations.[13]

The aggregate stock of human capital ($MHC_{Stock,y}$) is calculated by summing the future income streams for the entire population. This is done by summing the product of the per capita market human capital ($PCMHC_{y,s,a,e}$) and the population ($pop_{y,s,a,e}$) in each year, sex, age and education bucket ({y,s,a,e}).:

$$MHC_{Stock,y} = \sum_{s=1}^{2}\sum_{a=0}^{80}\sum_{e=0}^{18} pop_{y,s,a,e} * PCMHC_{y,s,a,e}$$

The use of current income information across ages, sexes, and educational attainment level to measure the lifetime income of the population for each year introduces some uncertainty. The use of differing discount rates can make expected earnings in the distant future matter more or less on the present valuation of future income. I produce a set of baseline estimates using a discount rate of 4%, following Jorgenson and Fraumeni (1989), and also provide sets of estimates using a range of discount rates in order to produce ranges of estimates that mitigate some of the future uncertainty in wage profiles each year.

4.2.1. Investment Estimates in the Jorgenson-Fraumeni Model

For each year, I measure how the present value of future wage streams has increased due to education obtained during that year. The approach holds per capita human capital constant, aging the population

[13] Earlier work in the literature Fraumeni et al. (2021); Schultz (1962); Jorgenson and Fraumeni (1989, 1991, 1992) also use workers' hourly wage to value their non-market time, resulting in more educated groups having higher value of non-market time. The non-market time ends up inflating per capita measures of human capital by a substantial amount within the income-based framework.

and advancing the education of the population to reflect the evolution of human capital advancement over the course of the year, which is the "net investment" method.[14] I calculate the net number of enrollees progressing through school each year. For each year, in each age/sex/education bucket, the population all age out of the education bucket ($AgingOut_{y,s,a,e}$). Those aging in y, s, a, e bucket are the surviving and enrolled fraction of the population, who advance to the bucket $y, s, a+1, e+1$ and the surviving and unenrolled portion of the population, who age into bucket $y, s, a+1, e$ (i.e., $AgingIn_{y,s,a,e}$). Aging into the bucket y, s, a, e are those a year younger with a year less education who were enrolled, and those a year younger who were unenrolled but had the same number of years of education and survived.

$$\begin{aligned} AgingOut_{y,s,a,e} &= pcount_{y,s,a,e} \\ AgingIn_{y,s,a,e} &= (1 - DeathRate_{y,s,a-1}) * erate_{y,s,a-1,e-1} * pcount_{y,s,a-1,e-1} \\ &\quad + (1 - DeathRate_{y,s,a-1}) * (1 - erate_{y,s,a-1,e}) * pcount_{y,s,a-1,e} \end{aligned}$$

$$NetAgingIn_{y,s,a,e} = AgingIn_{y,s,a,e} - AgingOut_{y,s,a,e}$$

The net educational attainment number is multiplied by per capita market human capital to obtain the yearly educational investment in market human capital for the year.

$$Invest_y = \sum_a \sum_s \sum_e NetAgingIn_{y,s,a,e} * PCMHC_{y,s,a,e}$$

The mechanical movement of the population into higher ages and educational attainment categories over the course of a year leads to higher expected future earnings paths. The model holds constant $PCMHC_{y,s,a,e}$, which is a per capita price on the human capital supplied by people in bucket $\{y, s, a, e\}$, and allows the quantity of people in the bucket to change over time. The shift in the population to, on

[14] A series of papers, Christian (2010, 2014); Fraumeni et al. (2017); Christian (2017), define this measurement as "net investment." Technically, investment in human capital measured this way captures both the increase in lifetime earnings due to increased lifetime earnings and a decrease in lifetime earnings due to aging.

average, older and more educated demographic buckets leads to shifts in the human capital stock over time.[15]

4.3. Changes to GDP Level

I use the cost-based and income-based methods to produce adjusted versions of GDP.[16] Under the cost-based framework, GDP increases by the indirect time costs of education and training as well as the intermediate spending of firms on educational services in BEA's input-output tables.

Adjusting GDP for income-based measurements of human capital investment boosts GDP not by short term spending in education, but by the resulting future income generated from the corresponding year's educational enrollment. I first remove direct spending on education and training from GDP, as this is now a redundant form of intermediate spending. I then add the estimates of investment which are the incremental impact on lifetime earnings due to educational obtainment in each year.

4.4. Return on Investment

The cost-based and income-based methods provide different estimates for investment on education. The difference between the dollars and time invested in education and the incremental return to lifetime earnings for education undertaken can be framed as a profit to households, or as gross operating surplus of the education sector (Abraham (2010); Liu (2015)). Since time and money invested in education produces more than the sum of its parts in returns to lifetime earnings, a return on investment can be calculated.

I use an internal rate of return calculation to calculate a rate of annual return on education using the

[15] Mechanically, this is subtracting a person from the current year's bucket $\{y, s, a, e\}$ and putting them in the bucket $\{y, s, a+1, e+1\}$ if they are enrolled or $\{y, s, a+1, e\}$ if they were not enrolled. So the difference captured in $erate_{y,s,a,e} * PCMHC_{y,s,a+1,e+1} + (1 - erate_{y,s,a,e}) * PCMHC_{y,s,a+1,e} - PCMHC_{y,s,a,e}$ is multiplied by the typical person shifting out of $\{y, s, a, e\}$.

[16] Gu and Macdonald (2016) and Fraumeni et al. (2017) also outline how incorporating human capital investment into GDP would proliferate through other BEA accounts, including production accounts, income, savings, and expenditure accounts, accumulation accounts, and private national wealth accounts.

cost-based and income-based method. In Friedman and Kuznets (1945), the authors frame professional education as a capital investment, where students incur costs in exchange for higher income streams in the future. The internal rate of return is the discount rate that equates the present value of costs with the present value of the discounted future income stream. I use this framework to back out the annual rate of return of education. I run the model over a range of discount rates between 0% and +20%, and find the rate that produces lifetime earnings estimates that best match the path of spending on education.

It is important to note that the investment in education from an individuals perspective cannot be diversified, so it is arguably a risky asset (Abraham (2010)). As with any risky asset, a high return is necessary to justify the investment at an individual level, which would imply that individuals use a higher discount rate to compute an individual rate of return. However, the rate of return computed here is from a societal perspective, where the aggregate risk is lower and a lower discount rate of 4% is applied, as discussed previously. This low discount rate may lead to a high societal rate of return.[17]

5. Results

5.1. Investments in Human Capital

Figure 1 presents real investment in constant chained 2017 dollars from 1994 to 2023 under each method. Table 2 lists corresponding numerical estimates of investment in non-human and human capital as well as GDP estimates. Investment in non-human capital (i.e., physical and intangible forms of capital already included in the accounts) is listed for comparison. For each method, I list investment in trillions of nominal dollars, investment in trillions of real 2017 dollars, adjusted GDP, and investment as a fraction of the adjusted GDP. The first five columns of the table list estimates for 1995, 2000, 2005, 2010, and 2015, followed by estimates for each year between 2018 and 2023. The final column details the average annual growth rate between 1995 and 2023 associated with each of the estimates.

Investment in non-human capital serves as a comparison, and it rises from $1.59 trillion in 1995 to $5.86

[17] In fact, Abraham (2010) suggests potentially computing both private and societal returns.

trillion in 2023. Nominal cost-based investment in human capital rises steadily from roughly $760 billion in 1995 to about $2.6 trillion in 2023. Nominal income-based investment begins at approximately $2.8 trillion in 1995 and ends near $6 trillion in 2023. The 2008–2011 peak in the income-based measure reflects higher college enrollment rates during the Great Recession (Goodman and Winkelmann (2025)).

Inflation matters for estimates between 2020 and 2023. When converted to constant 2017 dollars using the PCE deflator, the cost-based measure grows from roughly $1.1 trillion in 1994 to $2.2 trillion in 2023. The income-based measure increases from about $4.1 trillion to $5.1 trillion over the same period, with the Great Recession bump remaining.[18]

Cost-based investment in human capital makes up about 10% of adjusted GDP over the entire 1995–2023 period. Gross investment in non-human capital is around 20% of GDP. Income-based measures of human capital investment begin at 28% of GDP in 1995 and falls to an amount around 19% of GDP in the 2010s and early 2020s.

The overall population grows and the enrolled population fluctuates over the study period. Table 3 lists estimates of investment in human capital per student, and per capita. Real cost-based investment per student grows at 2 percent per year, which is right around the real growth rate of gross investment in non-human capital. While real income-based investment per student and per capita is at a much higher *level* than cost-based investment per capita, it is growing at a more muted rate. Meager growth in income-based investment per pupil means that the mean incremental earnings from investing in an additional year of education have not changed much since the 1990s. Real income-based investment per capita has a slightly negative growth rate, because enrollment rates have decreased in recent years, as discussed in the following section.

Investment under the income-based method is the incremental increase in the streams of future income for all students enrolled in education during the year. The choice of future discount rate impacts the valuation of this investment. The baseline choice of a discount rate of 4% (Jorgenson and Fraumeni, 1989) reflects the value of money or the risk-free rate of return. When individuals invest in their human capital, they take on risk because human capital is not diversified, and so they might require a higher rate of return to make the investment. In contrast, at a societal level, developing human capital in the

[18] Volatility in 2021 is evident in the cost-based series, driven by fluctuations in CPS wage estimates used to value student time.

population is less risky, meaning future returns to this investment should be less discounted (Abraham, 2010). In addition, changing the discount rate greatly impacts the results produced by the income-based method. Thus, it's both useful and transparent to provide different sets of output for a range of discount rates.

Table 4 lists income-based human capital investment between 1995 and 2023 under different assumptions about the discount rate. For the lower discount rates, the measure of net investment is volatile. These estimates are based on net aging and educational attainment through the population during the year, times the valuation of per capita human capital. Net aging and educational attainment may be negative in any one population bucket. Per capita human capital is higher under models with low discount rates, and differences due to both aging and educational attainment have a more persistent effect across lifetime earnings when the future is less steeply discounted.

5.2. Human Capital Stocks in the Fixed Asset Accounts

The income-based stock of human capita for the population is obtained by multiplying per capita market human capital $PCMHC_{y,s,a,e}$ by the population count associated with each age/sex/education/year group $Pop_{y,s,a,e}$, and summing across all $\{y, s, a, e\}$ buckets in the year. This process aggregates the discounted expected future wages for the entire population based on the current year's wage structure and future enrollment expectations. The stock is therefore the present value of all the future expected wage streams in the population as measured by that year's population wage profile.

$$HCStock_y = \sum_s \sum_a \sum_e PCMHC_{y,s,a,e} * Pop_{y,s,a,e}$$

Table 5 lists estimate for the stock of human capital from the income-based method under different assumptions for the discount rate, along with the stock of physical and intangible capital for comparison. Discount rates have a large impact on estimates. In the baseline model for which a discount rate of 4% is used, and the present value of all streams of future income of the population is along the lines of \$180 trillion to \$354 trillion. This is multiple times the value of the physical capital stock and intangible capital stock combined, which ranges from \$31 trillion in 1995 to \$75 trillion in 2023.

Table 6 lists the stocks and net investment in human capital from the income-based method and cost-based model under different assumptions about the depreciation rate. These human capital stocks are followed by the stocks of physical and intangible capital types for comparison. Income-based stocks range from about $182 trillion to $354 trillion. However, from the earlier Table 5, one can see that this range is sensitive to assumptions about the discount rate. Cost-based stocks range from $16 trillion to $39 trillion; the physical and intangible capital stock estimates range between $21 trillion and $90 trillion. In the baseline income-based method, the present value of all streams of future income of the population is multiple times the values of the estimates for both cost-based human capital stock and the physical capital stock and intangible capital stock combined.

5.3. Return on Investment

The ratio of income-based to cost-based investment averages roughly 3 to 1 over the sample period, consistent with earlier findings in Christian (2014) and Abraham and Mallatt (2022). The practice of narrowing this gap can be used to calculate a rate of return for investments in human capital. Figure 2 graphs cost-based estimates of investment, the nearest income-based investment, and the discount rate that forces the income-based estimate to be closest to the cost-based estimate for each year. The internal rate of return is a discount rate that makes the upfront costs of an investment (cost-based estimates) and the discounted present value of future income streams (income-based estimates) equal to one another. Internal rates of return between 18 and 19 percent best fit the cost estimates from about 1994 to 2000, and a range between 14 and 15 percent best fits the cost estimates in the late 2010s and 2020s. This range of values matches the internal rates of return for professional education (doctors and lawyers) calculated in Friedman and Kuznets (1945), who found 10–20% returns.

The apparent fall in return from about 19% to about 15% over time suggests that returns to education in comparison with costs may be decreasing over the study period. This may be due to differing growth rates between the cost of obtaining education and the income gain from having it. From the estimates of cost per student in Table 3, per-student cost-based investment is growing at a real rate of 2.02% annually; real lifetime income per student is only growing at a rate of 0.3% annually, so over time this difference in growth may impact the internal rate of return.

Many factors, such as enrollment rates, hours worked, wages, and the wage return of education have an impact on the income-based estimate for investment in human capital. Figure 3 plots these factors for young adults in the data with 12 or more years of education. Slowing rates of growth in investment per capita may be driven by falling enrollment rates, especially among young men. Inflation-adjusted wages have increased in recent years, wage premiums associated with more education have held steady, and annual hours worked have not changed noticeably. From these workforce dynamics, I conclude that the fall in human capital investment in the 2020s is likely not driven by changing wages, hours worked, or wage premiums from more education. The fact that costs are rising at a faster rate than income-based investment along with declining enrollment rates may drive decreasing internal rates of return. These findings are consistent with recent literature demonstrating a flattening of the college wage premium (Bengali et al. (2025, 2023); Valletta (2018)) and college costs growing at a rate outpacing monetary inflation (Cooper (2025); Cai and Heathcote (2022)).

5.4. Impact of Human Capital on GDP Measurement

Including human capital investment in GDP raises its level. Figure 4 plots GDP over time, GDP over time adjusted for cost-based investment in human capital, and GDP over time adjusted for income-based human capital. GDP is on average 2.59% higher in the cost-based model (without depreciation) and 14.75% higher in the income-based method.

While incorporating human capital investment into GDP raises its level, income-based human capital grows at a slower pace on average over time, and so decreases the rate of GDP growth. In Table 2, unadjusted real GDP grows at an average rate of 2.59%. Augmenting GDP with cost-based investment does not change the growth rate of GDP; the magnitude of the indirect costs of education are not large enough to impact its growth. However, augmenting GDP with income-based investment causes the growth rate to fall to 2.16%. The magnitude of income-based investment is larger, and grows at a slower rate than GDP, so its addition to GDP has more impact on the series.

Having human capital investment in GDP also influences the measurement of economic activity during economic downturns. Since these newly incorporated investment measures make up 10 to 30 percent of adjusted GDP each year, any pro-cyclicality or counter-cyclicality in human capital investment will impact the measurement of recessions. Figure 5 plots the growth in unadjusted real GDP, real GDP adjusted with the cost-based method, and real GDP adjusted with the income-based method during time periods covering the Great Recession (2007 to 2012) and the COVID–19 downturn and recovery

(2018 to 2023). The graphs plot the growth in GDP measures from a baseline of either 2007 for the Great Recession, or 2019 for the COVID–19 dip. Including education investment in GDP mediates some of the effects of the 2008 to 2010 economic contraction; GDP fell in 2009 to -2.91% lower than 2007's level but only contracted to -2.7% or -1.01% when accounting for cost- or income-based investment, respectively. In the 2011–2012 period, growth in adjusted GDP is slightly lower than the unadjusted GDP due to a drop in enrollment in the CPS that year. From this result, one may conclude that investment in human capital tends to have a counter-cyclical impact on economic activity, as students got more education and the income-based investment increased during the Great Recession.

However, for the COVID–19 downturn, for the income-based GDP measurement, the contraction is found to be *worse*; unadjusted GDP fell 2.33% in 2020 from the 2019 baseline, but if counting human capital investment, GDP would have contracted 3.35%. This means that lifetime earnings estimates dropped more dramatically than the rest of the economy and thus dragged adjusted GDP growth down further during COVID. Furthermore, based on income-based GDP estimates, it appears that the recovery from 2021 to 2023 was slower than it was in unadjusted GDP. In 2023, unadjusted GDP had recovered to a level 10.9% higher than 2019's baseline. This figure was only 8.07% under the income-based adjusted GDP. This result is in sharp contrast to educational investment during the Great Recession, which was counter-cyclical and a moderating force to GDP contraction.

The contrasting episodes of the Great Recession and COVID-19 period and recovery are driven by differing enrollment rates. The first graph in Figure 3 demonstrates that college enrollment spiked during the Great Recession, and was much lower in 2020 and fell, especially among young men, in 2021–2023.[19] This juxtaposition in enrollment rate movements around the economic downturns drives the differences in human capital investment, which in turn affect growth in GDP.

5.5. income-based method Sensitivity

Table 8 lists robustness results for human capital investments where the baseline income-based method is changed. I change inputs into the baseline human capital model, and then report the percentage of the baseline model's investment estimate for new income-based estimates across years for each change. In Panel A, I re-run the model using a discount rate of 10 percent and a discount rate of 20 percent. In

[19] NCES Table 302.60 also confirms this enrollment pattern for young men.

1995, under a discount rate of 10 percent, the estimate for investment is 53.73 percent of the baseline level. In Panel B, I hold population level, the population distribution, enrollment rates, wages, hours, or the survival rate constant at 1995 levels, respectively. By holding these metrics at their 1995 levels, I am shutting down variation over time in each of these data series that determine the human capital makeup over time.

Table 8 shows which model assumptions and data inputs most affect estimates of human capital investment. The end estimates are by far the most sensitive to changing the discount parameter in the model. However, it is also useful to see which real trends in demographic makeup and economic outcomes drive results. The results in the first row of Panel B are under a model where I hold the population level constant at its 1995 level, but allow the demographic share (the share of the population sorting into $\{y, s, a, e\}$ buckets) to evolve as it naturally does. The 2023 level is at a level 78.69 percent of the baseline model's, likely due to the population aging over the time period. The next row holds the demographic share constant, but still allows population to grow as it really did between 1995 and 2023; under this model, investment experiences higher growth because we are using the younger population distribution of 1995 while increasing the population. The next row is for a model where both population level and demographic shares are held at their 1995 level; having the younger population distribution of 1995 helps driving investment up, but having a lower population drives investment down as compared to the baseline model.

In the next row, I hold school enrollment rates constant at their 1995 level. Enrollment rates in 1995 were lower than enrollment rates in 2010 during the Great Recession, and investment estimates are 89 percent of the baseline in that year. For most of the rest of the years, the investments are higher under the 1995 enrollment rate. The next row holds wages constant at their 1995 levels. Investment estimates decrease because, in reality, average real wages rose in the 2010s and 2020s. In the next row, I hold hours worked at the 1995 level and growth in investment increases because hours worked per capita were higher in the 1990s. The next row holds survival rates by age and sex constant at the 1995 level, and it appears that this aspect of the model does not impact investment amounts as much, likely due to low variation in the mortality rates over time among the young.

The overall takeaway from this robustness exercise is that the output of the human capital model is fairly sensitive to inputs into the model. An extended version of this accounting framework for human capital may report additional ranges of estimates to account for this sensitivity.

5.6. Demonstrating the Accounting Framework as a Experimental Tool: Increases in Post-Secondary Enrollment Can Increase Human-Capital Augmented GDP

In this section, I demonstrate how the proposed framework can be used to assess how changes in educational enrollment can drive economic growth. Treating increases in educational enrollment as investment in human capital can impact how enrollment patterns influence the measurement of GDP. In traditional GDP, if more high school graduates chose to pursue vocational degrees, GDP may shrink if forgone wages reduce consumption to a greater degree than education spending increases consumption. In contrast, in the accounting framework for human capital, additional enrollment causes short-term forgone wages, but relatively larger increases in future income and output due to the development of the nation's human capital assets, and accounting for human capital as investment can increase the measure of GDP if those gains are accounted for.

Given the renewed public and policymaker interest in vocational degrees and technical education, I analyze how a change in educational training impacts GDP using the framework. Goodman and Winkelmann (2025) find that community college students are more sensitive to labor market conditions, and Schanzenbach and Turner (2022) finds that the drop in community college enrollment among men during the COVID-19 downturn is explained by a decrease in the supply of Assembly, Maintenance, and Repair course availability. I run a modeled experiment where 5 percent of the male population with high school degrees and no college are enrolled in two year vocational programs.[20] I calculate the impact of this policy intervention by calculating the return to lifetime incomes. Mechanically, within the income-based method, I examine unenrolled men with 12 years of education, who will receive an expected $PCEarnings_{y,s,a,12} + PCMHC_{y,s,a+1,12}$. This analysis examines how this type of policy could affect future income of this unenrolled group and how it would impact GDP.

I re-run the entire human capital model to capture the effect on the representative person in each {y,s,a,e} bucket where: all people with 12 years of education are required to enroll in a 2-year degree.

[20] In the CPS, trade school and vocational school educational attainment are grouped in with other two-year programs. The relevant survey question and reply reads "Highest level of school completed or degree received: Associate degree-occupational/vocational."

This will give me a per capita effect, which I can scale up to 5% of the young adult male population. The main way to influence the model is to alter enrollment probabilities. To simulate enrollment in a 2-year program, the enrollment rate for those with 12 years and 13 years of education is equal to 1, and the enrollment probability for those with 14 years of education is equal to zero.[21]

As part of this demonstration, I assume there are forgone earnings associated with this program. In this setup, the newly enrolled males are required to get 1,300 hours of schooling during the year. These hours come out of their working hours—if working hours in the associated group are greater than 1,300, the hours fall by 1,300, and if the working hours are less than 1,300 hours, they fall to zero.

Figure 6 plots discounted future expected lifetime earnings for men with 12 years of education using 2019 data. The red line is expected discounted lifetime earnings of high school grads who enroll in college next year. The blue line is lifetime earnings for men with 12 years of education who are not enrolled in the present year. The gap between the two reflects the gain in lifetime earnings associated with the choice to obtain a 13th year of education, and reflects not only real returns to education but also selection and differing future enrollment probabilities. Individuals who enroll in college are more likely to obtain college and other advanced degrees. The gray line plots the lifetime earnings from my simulated policy experiment where those with 12 years of education are forced into 2 additional years of school but then stop.

Accompanying Table 7 lists the expected discounted lifetime earnings for males in 2019 between the ages of 18 and 33 with 12 years of education. The table lists age, followed by columns covering the lifetime earnings for those who are enrolled and will complete the 13th year of education (corresponding to the red line in Figure 6), those who are unenrolled and will realize a lower future earnings path (the blue line in Figure 6), and those who enroll in a 2-year program then discontinue education once 14 years of education are obtained (the gray line in Figure 6). The next column lists the gain in lifetime earnings between the vocational group and the unenrolled group, and the last column lists forgone earnings due to additional time spent during one additional year of educational attainment.

[21] I don't allow for regular enrollment rates for those with 14 years of education because of selection associated with the education decision for those who were enrolled in education in the real world. For example, a graduating high schooler who will not attend college in the real world is not going to have the same probabilities of getting a bachelor's and master's degree as someone who chose to get those 13th and 14th years of education.

At the individual level, the mean lifetime earnings premium from the 2-year program is approximately $290,000. Forgone wages from reduced work hours are about $25,000 for each of two years, so the net gain from this intervention is $240,000 in lifetime earnings per impacted male.[22] If a career is 40 years long, this is equivalent to approximately a $6,000 boost in yearly earnings.[23] According to the U.S. Bureau of Labor Statistics (BLS), in 2019, the average earnings for those with a high school diploma but no college was $39,000 per year and the average earnings for those with some college or a 2-year degree was $45,400 per year—exactly in line with the estimated gains to lifetime wages from this exercise.

There are 11.3 million men between 18 and 33 with 12 years of attained education in 2019 who are not enrolled in the 13th year of education. 5% of this group represents 565,000 men attending a 2-year program, which is a huge influx in students, as 393,000 men earned associate's degrees in 2019–2020.[24] Having 5% of the unenrolled 11.3 million men attend a 2-year program would result in a $163.85 billion[25] increase in educational investment in the form of increased lifetime earnings resulting from two years of investing. It would also cost $50,000 per enrollee ($25,000 per year) in forgone wages or $28.25 billion over two years. According to campus.edu, associate's degrees including room and board cost about $11,600 per student per year, so these cost estimates would imply an additional $13.1 billion in fees.[26]

If we ignored the future return, GDP would decrease by $28.25 billion over two years due to lost earnings, but that would be offset by $13.1 billion in extra education spending, for a net $15.15 billion decrease in GDP over two years, or about a 0.0308% drop in GDP in 2019 and 2020. However, the proposed framework would count this as investment and account for the increase in future lifetime earnings due to the human capital investment. In this framework, this would add $163.85 billion in human capital investment, reflecting the increase in future income, and subtract $13.1 billion in direct spending and $28.25 billion of forgone wages, and reach a figure of $122 billion in net investment. This is a net swing to GDP of $137.65 billion, a 0.27% boost to GDP in 2019 and 2020.

This example illustrates the importance of the framework and its usefulness for policy analysis. Using current national accounting measurement practices that do not treat human capital as an asset, investments in human capital might drive down measured GDP due to forgone wages during the period of

[22] $290,000 - 2* $25,000

[23] $240,000 / 40 years = $6000 per year

[24] https://nces.ed.gov/programs/PES/section-6.asp#2;NCESTable318.10.

[25] $290,000 * .05*11.3 million enrollees

[26] $11,600 * 565,000 enrollees * 2 years

investment. In contrast, the accounting framework for human capital reflects the value of the investment the year the investment took place, more than offsetting the forgone wages.

6. Discussion and Potential Extensions

The policy implications of these findings are substantial. Recognizing human capital investment in the national accounts would align U.S. practice with the treatment of other intangible assets, provide a more complete measure of national wealth, and improve the basis for long-term fiscal and growth projections. The ability to track changes in human capital by educational level, demographic group, and economic cycle could inform education policy, workforce development strategies, and assessments of international competitiveness. Moreover, quantifying the returns to educational investment at the aggregate level provides a new tool for evaluating the societal investment in this asset class and better evaluates the level, mix, and potential return on investment.

As mentioned at the outset, the relationship between human capital and growth has been of longstanding interest. The estimates of investment-based human capital may offer a direct measure of human capital investment for use in neoclassical growth models (Lucas et al., 1988; Romer, 1989; Mankiw et al., 1992). Using this more specific measurement for human-capital-augmented labor may change the interpretation of results derived from these models and the factor share of productivity driven by physical capital, other intangible capital like R&D and software, residual multifactor productivity growth,[27] and human capital itself.

Although this framework has many uses, additional extensions could broaden its utility. The analysis treats years of schooling as the primary human capital input, but field of study and degree type significantly affect future earnings. Future work could disaggregate investment by educational specialization—distinguishing between high-tech degrees, trade certifications, and liberal arts education—to provide more nuanced policy guidance.

This paper only considers spending and investment in formal education as generating human capital.

[27] Fraumeni, Christian and Samuels (2015) detail how including human capital investment in GDP affects the measurement of multifactor productivity.

Other work has encouraged accounting for other inputs into human capital, like training, including on-the-job training (Brathaug et al., 2020) and experience (Arrow, 1962; Mincer, 1974). Future work could supplement the impact of formal education with detailed data on training and experience.

Numerous areas where the accounts could be extended and more closely connected to the official accounts has been developed in Fraumeni et al. (2017). This would include updating the production and factor outlay accounts; the income, receipt, and expenditure accounts; the capital accumulation accounts; and the wealth accounts.

Future research could produce a human capital accounting framework at more granular levels. State-level accounts using small area estimation methods for demographic groups with limited data would help policymakers understand how education impacts lifetime earnings across regions. Similarly, CPS industry and occupation data could enable breakdowns of human capital investment and returns by economic sector, revealing which industries benefit most from educational investment.

Case and Deaton (2015, 2021, 2022) documents growing mortality gaps between more and less educated Americans due to "deaths of despair"—deaths from alcohol, drugs, and suicide. The current model assigns survival rates by age, year, and sex but could incorporate education-specific mortality rates. This extension would illuminate how widening life expectancy gaps between education groups affect expected lifetime earnings and reveal additional health-related benefits of human capital investment.

Since returns are derived from projected lifetime earnings, they are inherently uncertain; as Table 4 and Section 5.5 show, plausible assumptions yield a range of estimates. The estimates are sensitive to modeling choices, particularly the discount rate. Additionally, data constraints limit the precision with which some indirect costs—such as the value of non-market time—can be measured. A more comprehensive account framework for human capital may provide a range of values for a broader set of estimates.

The issues highlighted in this section point to the importance of continued extensions of both data and methodology to further improve human capital measurement.

7. Conclusion

This study contributes to the ongoing effort to measure investment in human capital and to expand the frontier of GDP measurement. Historically, investment in the accumulation of knowledge and skills within the population has been recognized by economists as an important source of economic growth, yet it has remained challenging to incorporate human capital into the system of national accounts. This paper adds to the existing discussion on human capital accounting by extending prior work by Christian (2010, 2014, 2017) and Fraumeni et al. (2017) to cover the time period 1994–2023, detailing patterns during periods of economic recovery and crisis. Following most of the rest of the accounting literature, this paper focuses on formal education's role in generating additional human capital, abstracting away from the roles of training or informal learning that may generate human capital due to lack of detailed data in U.S. surveys.[28]

The addition of these human capital investments substantially augments conventional measures of GDP. By including estimates of time costs (i.e., student time and parent time dedicated to educational attainment) and reclassifying firms' intermediate spending on educational services as investment, GDP gets a boost. Specifically, GDP is increased by 2.59% under the cost-based method and 14.75% under the income-based method adjusted for human capital. The magnitude of this impact shows the significant magnitude of estimates of human capital investment, with real cost-based investment increasing from $0.76 trillion in 1995 to about $2.66 trillion in 2023, consistently making up about 10% of adjusted GDP. Moreover, cost-based human capital investment makes up about half the level of gross investment in other forms of capital in the accounts, including investments in equipment, structures, residences, and intellectual property products such as software and R&D. The approach taken is conceptually comparable to how BEA has incorporated other forms of intangible capital like software and R&D.

The findings of this proposed framework study emphasize the importance of accounting for human capital in understanding economic growth and a country's long term economic growth potential. It provides a more complete picture of economic activity, extending the boundary of what is considered investment within GDP. The rich data underlying the models sheds light on the impact of demographic

[28] The UNECE guide for creating a Satellite Account for Education and Training provides guidelines for data in other countries that would be available for generation of a fuller account of human capital (Brathaug et al. (2020)).

factors such as age, sex, and educational attainment of the population on growing the nation's stock of productive human capital. This study provides groundwork for continued research and development into human capital accounting, with a goal to provide policymakers and the public with more comprehensive and accurate understanding of the nation's true wealth and its drivers of growth.

References

Abraham, K. G. (2010). Accounting for investments in formal education. *Survey of Current Business 90*(6), 42–53.

Abraham, K. G. and C. Mackie (2006). A framework for nonmarket accounting. In *A New Architecture for the US National Accounts*, pp. 161–192. University of Chicago Press.

Abraham, K. G. and J. Mallatt (2022). Measuring human capital. *Journal of Economic Perspectives 36*(3), 103–130.

Aizcorbe, A. M., C. E. Moylan, and C. A. Robbins (2009). Toward better measurement of innovation and intangibles. *Survey of Current Business 89*(1), 10–23.

Arrow, K. J. (1962). The economic implications of learning by doing. *The Review of Economic Studies 29*(3), 155–173.

Baldwin, J. R., G. Gellantly, and M. Tanguay (2007). Depreciation rates for the productivity accounts. *The Canadian Productivity Review*.

Barro, R. and X. Sala-i Martin (2004). Economic growth second edition.

Barro, R. J. and J.-W. Lee (1993). International comparisons of educational attainment. *Journal of Monetary Economics 32*(3), 363–394.

Barro, R. J. and J.-W. Lee (2001). International data on educational attainment: updates and implications. *Oxford Economic papers 53*(3), 541–563.

Barro, R. J. and J. W. Lee (2013). A new data set of educational attainment in the world, 1950–2010. *Journal of Development Economics 104*, 184–198.

Becker, G. S. (1962). Investment in human capital: A theoretical analysis. *Journal of Political Economy 70*(5, Part 2), 9–49.

Becker, G. S. (1964). Human capita. *New York: National Bureau of Economic Research*.

Bee, C. A., C. Hokayem, and D. C. Lin (2022). Modeling the 2021 child tax credit in the cps asec. *United States Census Bureau Social, Economic, and Housing Statistics Division [SEHSD] Working Paper 17*.

Bengali, L., M. Sander, R. G. Valletta, and C. Zhao (2023). Falling college wage premiums by race and ethnicity. *FRBSF Economic Letter 22*.

Bengali, L., R. G. Valletta, and C. Zhao (2025). Explaining stagnation in the college wage premium. *IZA Discussion Papers* (17717).

Borjas, G. J. and D. S. Hamermesh (2024). The mismeasurement of work time: Implications for wage discrimination and inequality. Technical Report Working Paper 32025, National Bureau of Economic Research.

Brathaug, A. L., L. Popkova, W. Gu, J. Tebrake, I. Gonsch, O. Schmalwasser, A. Schneider, O. Hazan, N. Steinberg, A. Righi, P. Golberg, Vassilev, V. Antonopoulos, D. Webber, P. Passerini, A. Desurmont, T. Dimova, R. Peltola, S. Voffal, E. Legault, and I. Di Matteo (2020). Satellite account for education and training: Compilation guide.

Burkhauser, R. V., S. Feng, S. P. Jenkins, and J. Larrimore (2012). Recent trends in top income shares in the united states: reconciling estimates from march cps and irs tax return data. *Review of Economics and Statistics 94*(2), 371–388.

Cai, Z. and J. Heathcote (2022). College tuition and income inequality. *American Economic Review 112*(1), 81–121.

Case, A. and A. Deaton (2015). Rising morbidity and mortality in midlife among white non-hispanic americans in the 21st century. *Proceedings of the National Academy of Sciences 112*(49), 15078–15083.

Case, A. and A. Deaton (2021). Life expectancy in adulthood is falling for those without a ba degree, but as educational gaps have widened, racial gaps have narrowed. *Proceedings of the National Academy of Sciences 118*(11), e2024777118.

Case, A. and A. Deaton (2022). The great divide: education, despair, and death. *Annual Review of Economics 14*(1), 1–21.

Christian, M. S. (2010). Human capital accounting in the united states. *MS Cristian//Survey of Current Business* (6), 31–36.

Christian, M. S. (2014). Human capital accounting in the united states: Context, measurement, and application. In *Measuring Economic Sustainability and Progress*, pp. 461–491. University of Chicago Press.

Christian, M. S. (2017). Net investment and stocks of human capital in the united states, 1975-2013. Accessed as BEA Working Paper on March 25, 2026.

Cooper, P. (2025). Trends in net college tuition and financial aid, 1990–2020.

Corrado, C., C. Hulten, and D. Sichel (2009). Intangible capital and us economic growth. *Review of Income and Wealth 55*(3), 661–685.

Corral, P., N. Dehnen, R. D'Souza, R. Gatti, and A. Kraay (2021). The world bank human capital index. In *Measuring Human Capital*, pp. 55–81. Elsevier.

Eisner, R. (1978). Total incomes in the united states, 1959 and 1969. *Review of Income and Wealth 24*(1), 41–70.

Eisner, R. (1985). The total incomes system of accounts. *Survey of Current Business 65*(1), 24–48.

Eisner, R. (1989). *The total incomes system of accounts*. University of Chicago Press.

Fraumeni, B. M. and M. S. Christian (2020). Accumulation of human and market capital in the united states, 1975–2012: an analysis by gender. In *Measuring Economic Growth and Productivity*, pp. 509–529. Elsevier.

Fraumeni, B. M., M. S. Christian, and J. D. Samuels (2017). The accumulation of human and nonhuman capital, revisited. *Review of Income and Wealth 63*, S381–S410.

Fraumeni, B. M., M. S. Christian, and J. D. Samuels (2021). Accumulation of human and market capital in the united states: The long view, 1948–2013. In *Measuring Human Capital*, pp. 167–197. Elsevier.

Fraumeni, B. M. and S. Okubo (2005). R&d in the national income and product accounts: A first look at its effect on gdp. pp. 275–322. University of Chicago Press.

Friedman, M. (1955). The role of government in education.

Friedman, M. and S. Kuznets (1945). *Income from independent professional practice*. Number frie54-1. National Bureau of Economic Research.

Goodman, J. and J. Winkelmann (2025). Labor market strength and declining community college enrollment. Technical Report Working Paper 34498, National Bureau of Economic Research.

Graham, J. W. and R. H. Webb (1979). Stocks and depreciation of human capital: New evidence from a present-value perspective. *Review of Income and Wealth 25*(2), 209–224.

Gu, W. and R. Macdonald (2016). Human capital: Satellite account. In *UNECE Expert group on National Accounts*. Statistics Canada.

Gu, W. and A. Wong (2015). Productivity and economic output of the education sector. *Journal of Productivity Analysis 43*, 165–182.

Hulten, C. R. and F. C. Wykoff (1980). *The measurement of economic depreciation*. Urban Institute Washington.

Jorgenson, D. W. and B. M. Fraumeni (1989). The accumulation of human and nonhuman capital, 1949-84. In *The Measurement of Saving, Investment and Wealth*, pp. 227–286. National Bureau of Economic Research, via The University of Chicago Press.

Jorgenson, D. W. and B. M. Fraumeni (1991). *The output of the education sector*. Number 1543. Harvard Institute of Economic Research, Harvard University.

Jorgenson, D. W. and B. M. Fraumeni (1992). Investment in education and us economic growth. *The Scandinavian Journal of Economics*, S51–S70.

Kendrick, J. W. (1974). The accounting treatment of human investment and capital. *Review of Income and Wealth 20*(4), 439–468.

Kokkinen, A. (2011). *On Finland's Economic Growth and Convergence with Sweden and the EU15 in the 20th Century*. Ph. D. thesis, European University Institute.

Landefeld, J. S. and B. M. Fraumeni (2001). Measuring the new economy. *Survey of current business 81*(3), 23–40.

Liu, G. (2014). Measuring the stock of human capital for international and intertemporal comparisons. In *Measuring Economic Sustainability and Progress*, pp. 493–544. University of Chicago Press.

Liu, G. (2015). A stylized satellite account for human capital.

Liu, G. and M. Greaker (2009). Measuring the stock of human capital for norway–a lifetime labour income approach. *Statistics Norway Research* (2009/12).

Loewenstein, M. A. and J. R. Spletzer (1999). General and specific training: Evidence and implications. *Journal of Human Resources*, 710–733.

Lucas, R. E. et al. (1988). On the mechanics of economic growth. *Journal of Monetary Economics 22*, 3–22.

Mackie, C. and K. G. Abraham (2005). *Beyond the market: Designing nonmarket accounts for the United States*. National Academies Press.

Mankiw, N. G., D. Romer, and D. N. Weil (1992). A contribution to the empirics of economic growth. *The Quarterly Journal of Economics 107*(2), 407–437.

Mincer, J. (1958). Investment in human capital and personal income distribution. *Journal of Political Economy 66*(4), 281–302.

Mincer, J. A. (1974). Schooling and earnings. In *Schooling, experience, and earnings*, pp. 41–63. NBER.

Moylan, C. (2001). Estimation of software in the us national accounts: new developments. *Bureau of Economic Analysis Working Paper*.

Moylan, C. E. and S. Okubo (2020). The evolving treatment of r&d in the us national economic accounts. *BEA Papers*, 1–29.

Okubo, S., C. A. Robbins, C. E. Moylan, B. K. Sliker, L. I. Schultz, and L. S. Mataloni (2006). Bea's 2006 research and development satellite account. *Survey of Current Business 86*, 14–27.

Romer, P. M. (1989). Human capital and growth: Theory and evidence.

Salam, E. (2024). College enrollment is falling at a 'concerning' rate, new data reveals. *The Guardian*.

Samans, R., S. Zahidi, T. A. Leopold, and V. Ratcheva (2017). The global human capital report 2017: preparing people for the future of work. In *World Economic Forum, Geneva, Switzerland*.

Schanzenbach, D. W. and S. Turner (2022). Limited supply and lagging enrollment: Production technologies and enrollment changes at community colleges during the pandemic. *Journal of Public Economics 212*, 104703.

Schultz, T. W. (1962). Reflections on investment in man. *Journal of Political Economy 70*(5, Part 2), 1–8.

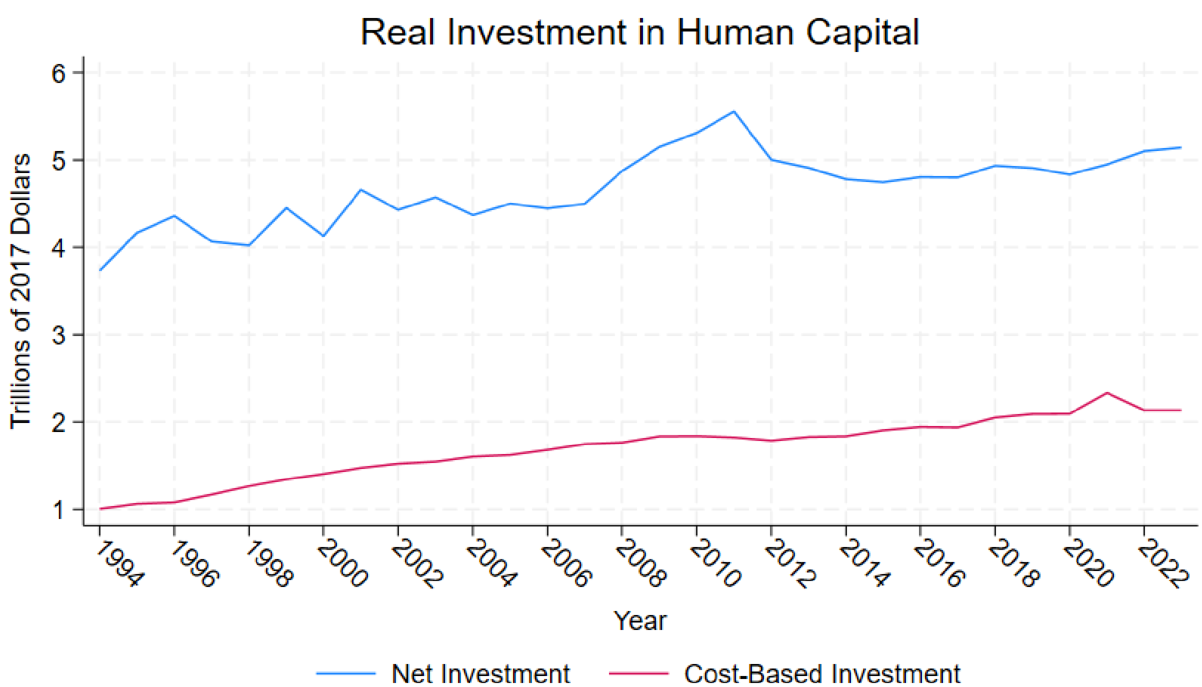
Valletta, R. G. (2018). Recent flattening in the higher education wage premium: Polarization, skill downgrading, or both? In *Education, skills, and technical change: Implications for future US GDP growth*, pp. 313–342. University of Chicago Press.

Table 1. Data Sources Used to Measure Cost-Based and Income-Based Human Capital

Cost-based model	
Household spending on education	NIPA PCE Table 2.5.5: PCE by function, line 95
Gross NPISH output, education services	NIPA PCE Table 2.4.5U: PCE by type of product, underlying detail, line 349
Less NPISH sales of education services to households	NIPA PCE Table 2.4.5U: PCE by type of product, underlying detail, line 362
Government consumption of education	NIPA Table 3.15.5, Government consumption by function, line 29
Intermediate Spending on Ed	Input-Output Accounts, The Use of Commodities by Industries, After Redefinitions (Producers' Prices) - Summary
Value of student time	Student hours spent in education times hourly wage , from income model (CPS)
Value of parent time	CPS Annual Averages, Table 39, Median weekly earnings of full-time wage and salary workers by detailed occupation and sex
	ATUS-X tabulation tool at https://www.atusdata.org/atus/sda/
	Time use category Activities related to household children's education
income-based method	
Years of education attainment	October Supplement of CPS
Wages earned	March ASEC CPS
Hours worked	March ASEC CPS
Tax adjustment	NBER TAXSIM Model
Survival rates	Social Security Administration Actuarial Life Tables by Age, Sex, and Year
Aggregate US Population counts	Census
Aggregate student enrollment counts	National Center for Education Statistics (NCES) Digest of Education Statistics: Tables 105.30, 203.10, and 307.10.
Birth counts	NVSS Aggregate Birth Counts by year, sex.
Death counts	NVSS Mortality Cause of Death Files
Inflation and price controls	PCE deflator

Notes. Columns display the mean per capita market human capital for the average person in each age group in 2019. The shift in enrollment population columns detail the net number of enrolled students aging out of (negative net enrollment) or into (positive net enrollment) each age group. The Total Investment is equal to the sum of the product of each year/sex/age/ed buckets net aging out of and into education times the corresponding PCMHC.

Figure 1. Real Investment Estimates, 1994 to 2023



Note: The figure plots spending investment in 2017 dollars under the cost-based model and net investment from income-based method, which is the amount that educational enrollment each year increases the present value of future earnings.

Table 2. Estimates of Investment in Human Capital

Year:	1995	2000	2005	2010	2015	2018	2019	2020	2021	2022	2023	Growth
Panel A: Nominal Estimates												
Gross Investment, Non-Human Capital	1.59	2.35	2.97	2.75	3.74	4.350	4.54	4.55	4.99	5.5	5.86	4.77%
Cost-Based Investment	.72	1.03	1.32	1.66	1.84	2.08	2.15	2.19	2.49	2.42	2.55	4.64%
Income-Based Investment	2.8	3.02	3.65	4.79	4.59	5	5.05	5.05	5.27	5.79	6.140	2.84%
GDP - Unadjusted	7.640	10.25	13.04	15.05	18.3	20.66	21.54	21.35	23.68	26.01	27.72	4.71%
Cost-Based Adjusted GDP	7.850	10.58	13.45	15.58	18.88	21.34	22.25	22.07	24.63	26.78	28.54	4.72%
Income-Based Adjusted GDP	9.73	12.25	15.38	18.18	21.05	23.58	24.44	24.22	26.47	29.38	31.31	4.26%
Panel B: Real Inflation-Adjusted Estimates												
Gross Investment, Non-Human Capital	2.36	3.21	3.66	3.05	3.86	4.29	4.41	4.36	4.69	4.850	4.91	2.65%
Cost-Based Investment	1.06	1.4	1.62	1.84	1.9	2.05	2.09	2.09	2.33	2.13	2.13	2.52%
Income-Based Investment	4.17	4.13	4.5	5.31	4.75	4.93	4.91	4.84	4.95	5.100	5.14	.75%
GDP - Unadjusted (Real)	11.36	14	16.07	16.69	18.89	20.38	20.94	20.46	22.24	22.9	23.23	2.59%
Cost-Based Adjusted GDP (Real)	11.68	14.45	16.58	17.28	19.5	21.05	21.63	21.14	23.12	23.58	23.92	2.59%
Income-Based Adjusted GDP (Real)	14.47	16.73	18.95	20.16	21.74	23.26	23.76	23.2	24.85	25.87	26.24	2.15%
Panel C: Investment in Human Capital as Fraction of Adjusted GDP												
Investment in Non-Human Capital	20.8%	22.96%	22.76%	18.26%	20.42%	21.05%	21.06%	21.31%	21.09%	21.16%	21.15%	.06%
Cost-Based	9.109%	9.720%	9.790%	10.64%	9.77%	9.74%	9.67%	9.9%	10.1%	9.040%	8.92%	-.07%
Income-Based	28.81%	24.69%	23.75%	26.34%	21.83%	21.21%	20.66%	20.84%	19.92%	19.72%	19.6%	-1.37%

Notes. The table lists nominal and real estimates of human capital investment under the cost-based and income-based models, as well as how accounting for human capital impacts GDP levels. All spending numbers in trillions of US dollars except for Cost Per Student amounts, which are in dollars. Real dollar amounts are in 2017 dollars and were adjusted using the PCE price deflator. The column titled "Growth" details the average annual rate of growth between 1995 and 2023 associated with the dollar measurement.

Table 3. Investment in Human Capital, Per Capita and Per Student

Year:	1995	2000	2005	2010	2015	2018	2019	2020	2021	2022	2023	Growth
Investment Estimates Per Enrolled Student												
HC investment (Cost) Per Student (Real)	18890.86	23443.93	25721.73	28167.36	29064.58	31297.55	31912.36	31867.06	36536.88	33409.63	33492.22	2.07%
HC Investment (Income) Per Student (Real)	74020.59	68968.2	71340.92	81370.7	72416.53	75347.7	74914.22	73594.8	77474.81	79936.92	80729.98	.31%
Non-Human Capital Investment Per Student (Real)	41963.69	53679.41	57979.39	46698.95	58888.41	65476.57	67328.86	66342.09	73403.3	75929.42	77117.61	2.2%
Investment Estimates Per Population												
HC investment (Cost) Per Popln. (Real)	4013.23	4995.97	5502.51	5952.440	5945.05	6266.76	6354.06	6308.16	7029.26	6383.93	6335.79	1.64%
HC Investment (Income) Per Popln. (Real)	15725.15	14697.33	15261.58	17195.58	14812.53	15087	14916.15	14568.26	14905.22	15274.4	15271.86	-.1%
Non-Human Capital Investment Per Popln. (Real)	8914.889	11439.24	12403.22	9868.610	12045.41	13110.48	13405.83	13132.57	14121.91	14508.64	14588.5	1.77%

Notes. The table lists per-capita and per-student estimates of human capital investment to account for population growth or enrollment changes over time. All spending numbers in trillions of US dollars except for Cost Per Student amounts, which are in dollars. Real dollar amounts are in 2017 dollars and were adjusted using the PCE price deflator. The column titled "Growth" details the average annual rate of growth between 1995 and 2023 associated with the dollar measurement.

Table 4. Estimates of Investment in Human Capital, By Discount Rate

Year:	1995	2000	2005	2010	2015	2018	2019	2020	2021	2022	2023	Growth
Estimates in Trillions of 2017 Dollars												
Discount = 0%	4.350	1.56	1.35	3.57	.89	.8	.12	.16	1.65	2.5	2.59	-1.84%
Discount = 1%	4.8	3.29	3.43	5.15	3.42	3.49	3.15	3.08	3.91	4.45	4.53	-.2%
Discount = 2%	4.77	4.02	4.32	5.65	4.49	4.64	4.47	4.37	4.83	5.17	5.25	.34%
Discount = 3%	4.52	4.21	4.57	5.600	4.81	4.99	4.91	4.82	5.06	5.29	5.34	.6%
Discount = 4%	4.17	4.13	4.5	5.31	4.75	4.93	4.91	4.84	4.95	5.100	5.14	.75%
Discount = 5%	3.79	3.91	4.27	4.92	4.51	4.69	4.69	4.64	4.68	4.78	4.81	.86%
Discount = 6%	3.42	3.64	3.97	4.5	4.19	4.37	4.39	4.350	4.350	4.42	4.44	.94%
Discount = 7%	3.07	3.36	3.66	4.09	3.86	4.04	4.06	4.02	4	4.05	4.07	1.01%
Discount = 8%	2.76	3.08	3.36	3.71	3.54	3.71	3.73	3.71	3.67	3.71	3.72	1.07%
Discount = 9%	2.48	2.82	3.08	3.38	3.24	3.4	3.42	3.41	3.37	3.39	3.4	1.13%
Discount = 10%	2.24	2.59	2.82	3.08	2.97	3.12	3.14	3.13	3.09	3.11	3.12	1.19%
Discount = 11%	2.03	2.38	2.59	2.81	2.73	2.87	2.89	2.89	2.84	2.86	2.86	1.25%
Discount = 12%	1.84	2.19	2.38	2.58	2.51	2.64	2.66	2.66	2.62	2.63	2.64	1.3%
Discount = 13%	1.67	2.02	2.2	2.37	2.32	2.44	2.46	2.47	2.42	2.43	2.44	1.35%
Discount = 14%	1.53	1.87	2.03	2.19	2.15	2.26	2.28	2.29	2.25	2.26	2.26	1.4%
Discount = 15%	1.4	1.74	1.89	2.03	1.99	2.11	2.12	2.13	2.09	2.1	2.1	1.45%
Discount = 16%	1.29	1.62	1.76	1.89	1.86	1.97	1.98	1.99	1.95	1.96	1.96	1.5%
Discount = 17%	1.2	1.51	1.64	1.76	1.74	1.84	1.85	1.86	1.83	1.83	1.84	1.54%
Discount = 18%	1.11	1.42	1.54	1.65	1.63	1.73	1.74	1.75	1.72	1.72	1.72	1.59%
Discount = 19%	1.03	1.33	1.45	1.55	1.53	1.63	1.64	1.65	1.62	1.62	1.62	1.63%
Discount = 20%	.96	1.26	1.36	1.46	1.45	1.54	1.54	1.56	1.53	1.53	1.53	1.67%
Investment in Non-Human Capital	2.36	3.21	3.66	3.05	3.86	4.29	4.41	4.36	4.69	4.850	4.91	2.65%

Notes. The table details estimates of investment in human capital in the income-based model, under different assumptions about discount rates used to discount future earnings in the lifetime earnings model. All spending numbers in trillions of US dollars. Real dollar amounts are in 2017 dollars and were adjusted using the PCE price deflator. The column titled "Growth" details the average annual rate of growth between 1995 and 2023 associated with the dollar measurement.

Table 5. Estimates of Stock of Human Capital, By Discount Rate

Year:	1995	2000	2005	2010	2015	2018	2019	2020	2021	2022	2023	Growth
Estimates in Trillions of 2017 Dollars												
Discount = 0%	481.7	704.0	794.4	843.4	906.3	985.1	1005.	949	947.2	929.9	940.0	2.42%
Discount = 1%	363.3	533.8	594.7	620.8	668.0	724.0	741.0	705.3	705.8	697.0	703.4	2.39%
Discount = 2%	281.8	416.1	458.8	472.9	509.8	552.0	566.1	541.8	544.1	540.2	544.5	2.38%
Discount = 3%	224.2	332.6	363.7	371.1	400.9	434.3	445.8	428.4	431.9	430.9	434.0	2.39%
Discount = 4%	182.4	272.0	295.5	299.0	323.8	351.0	360.6	347.6	351.9	352.4	354.8	2.4%
Discount = 5%	151.5	227.1	245.4	246.6	267.8	290.5	298.6	288.6	293.2	294.6	296.5	2.43%
Discount = 6%	128.1	193.1	207.7	207.6	226.0	245.4	252.4	244.4	249.1	251.1	252.6	2.45%
Discount = 7%	110.2	166.9	178.9	178.0	194.2	211.1	217.2	210.6	215.3	217.6	218.8	2.48%
Discount = 8%	96.15	146.3	156.4	155.0	169.5	184.5	189.8	184.3	189	191.3	192.3	2.51%
Discount = 9%	84.97	129.9	138.6	136.9	150.0	163.4	168.2	163.4	168	170.3	171.2	2.53%
Discount = 10%	75.95	116.6	124.2	122.3	134.3	146.4	150.7	146.6	151.0	153.3	154.1	2.56%
Discount = 11%	68.58	105.7	112.4	110.5	121.5	132.5	136.5	132.9	137.0	139.3	140.0	2.58%
Discount = 12%	62.47	96.64	102.7	100.7	110.9	121.1	124.7	121.4	125.5	127.7	128.3	2.6%
Discount = 13%	57.34	89	94.48	92.55	102.0	111.4	114.8	111.8	115.7	117.9	118.4	2.62%
Discount = 14%	53	82.48	87.53	85.63	94.52	103.3	106.4	103.7	107.4	109.5	109.9	2.64%
Discount = 15%	49.29	76.90	81.57	79.7	88.07	96.3	99.21	96.75	100.3	102.3	102.7	2.66%
Discount = 16%	46.08	72.05	76.41	74.59	82.5	90.25	92.98	90.7	94.13	96.04	96.42	2.67%
Discount = 17%	43.29	67.82	71.90	70.14	77.64	84.97	87.54	85.42	88.72	90.55	90.90	2.69%
Discount = 18%	40.84	64.09	67.94	66.23	73.37	80.33	82.76	80.78	83.96	85.72	86.04	2.7%
Discount = 19%	38.67	60.79	64.44	62.79	69.60	76.22	78.53	76.67	79.73	81.43	81.72	2.71%
Discount = 20%	36.75	57.85	61.32	59.72	66.23	72.56	74.77	73	75.97	77.60	77.87	2.72%
Capital Stock	31.56	37.53	46.11	52.12	57.97	61.53	63.8	65.34	66.78	71.36	75.84	3.18%

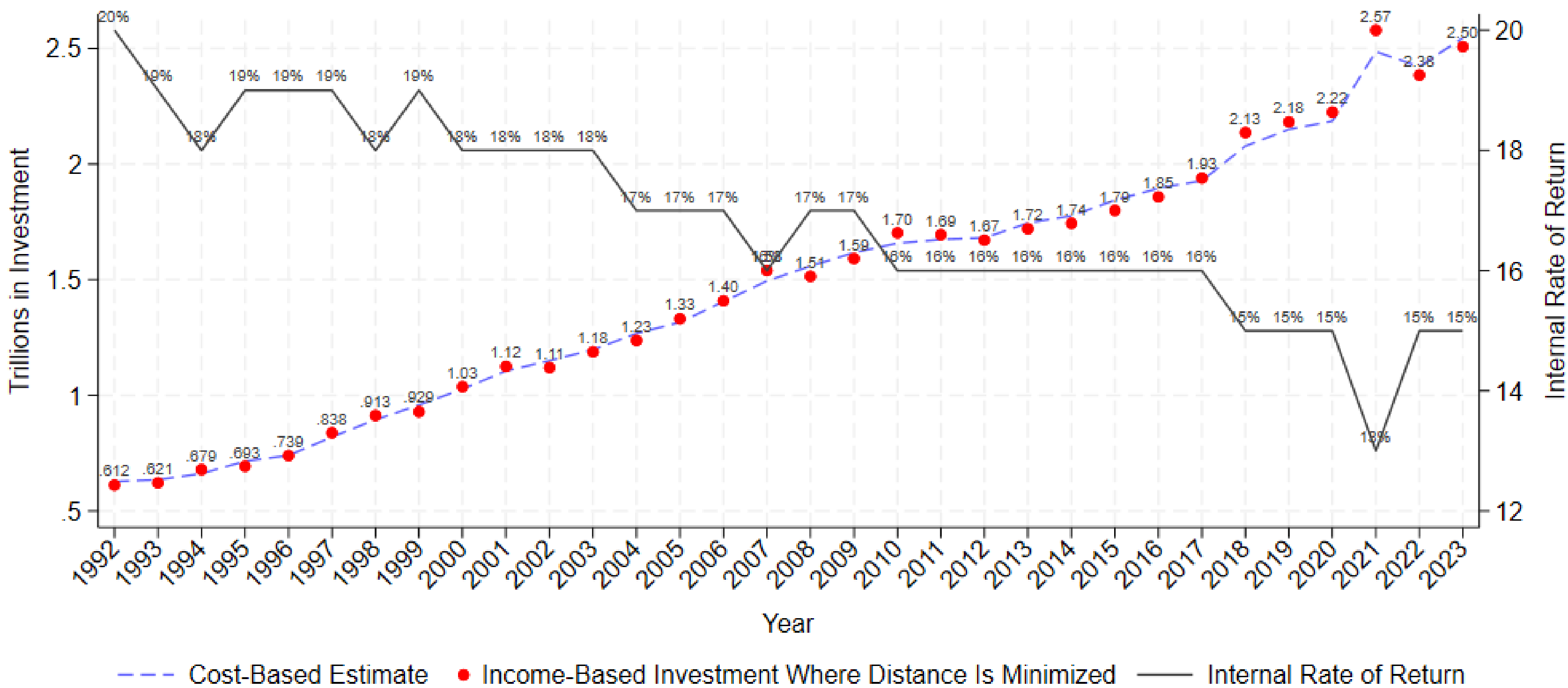
Notes. The table details estimates of stocks of human capital in the income-based model, under different assumptions about discount rates used to discount future earnings in the lifetime earnings model. All spending numbers in trillions of US dollars. Real dollar amounts are in 2017 dollars and were adjusted using the PCE price deflator. The column titled "Growth" details the average annual rate of growth between 1995 and 2023 associated with the dollar measurement.

Table 6. Stocks of Human Capital and Other Capital

Year:	1995	2000	2005	2010	2015	2018	2019	2020	2021	2022	2023	Growth
Human Capital, Income-Based, Billions of Dollars												
Stock, Human Capital (Real)	182452.91	272025.31	295537.09	299031.91	323882.28	351024.41	360664.97	347664.94	351909.16	352459.94	354806.53	2.4%
Human Capital, Cost-Based, Billions of Dollars												
Stock, Cost-Based Method, 4.4% Depreciation	25320.6	26295.3	28701.5	31409.3	33836.2	35516.8	36153.9	36763.0	37629.3	38199.7	38750.8	1.53%
Stock, Cost-Based Method, 6% Depreciation	19924.2	20564.7	22602.1	24869.1	26791.9	28150.7	28675.5	29169.2	29917.5	30363.5	30788.8	1.57%
Stock, Cost-Based Method, 7.5% Depreciation	16375.5	16825.0	18635.9	20611.8	22194.8	23338.2	23787.6	24203.4	24872.0	25232.7	25572.2	1.6%
Physical and Intangible Capital Stock, Billions of Dollars												
Total Stock	31557.1	37526.7	46111.8	52119.4	57974.5	61526.4	63803.6	65352.1	66780.0	71364.4	75836.1	3.18%

Notes. All spending numbers in billions of US dollars, adjusted for inflation. Income-based human capital stock is calculated through the J-F income-based model, and is equal to the present value of expected future income in each year, given the lifetime income paths constructed from all older groups during that year. Cost-based human capital stock is calculated using the perpetual inventory method, using varying discount rates. The physical and intangible capital stocks are from BEA's fixed asset accounts. The column titled "Growth" details the average annual rate of growth between 1995 and 2023 associated with the dollar measurement.

Figure 2. Internal Rate of Return



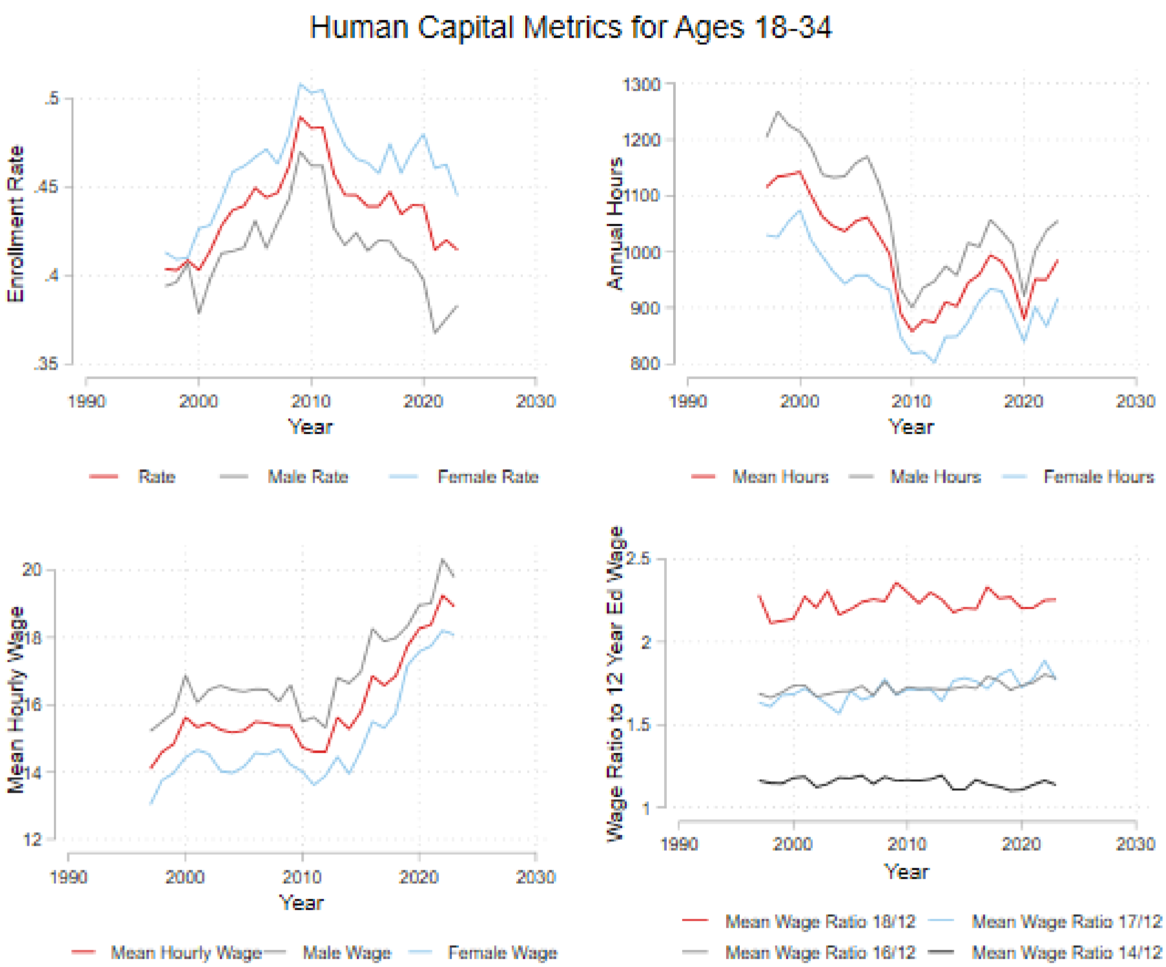
Note: The figure plots cost-based spending over time and the income-based measurement, where the distance between the cost-based and varying income-based estimate is minimized. On the right axis, the internal rate of return which minimizes the distance is plotted.

Table 7. Lifetime Income For Males with 12 Years of Education in 2019

Age	Lifetime Earnings Ed=12, Enrolled	Lifetime Earnings Ed=12, Unenrolled	Lifetime Earnings Ed=12, Vocational Track	Gain From Vocational	Foregone Wages
18	2,743,524.00	1,946,510.00	1,609,000.00	-337,510.00	-8,127.00
19	2,510,899.00	1,555,349.00	1,614,724.00	59,376.00	-9,349.00
20	2,206,335.00	1,441,045.00	1,623,685.00	182,640.00	-19,104.00
21	1,998,020.00	1,409,167.00	1,625,610.00	216,443.00	-19,046.00
22	1,849,735.00	1,402,849.00	1,626,394.00	223,545.00	-23,684.00
23	1,777,793.00	1,393,542.00	1,640,343.00	246,801.00	-26,115.00
24	1,742,046.00	1,381,006.00	1,635,727.00	254,721.00	-25,552.00
25	1,727,215.00	1,367,140.00	1,645,097.00	277,957.00	-27,968.00
26	1,674,597.00	1,364,222.00	1,623,278.00	259,056.00	-27,653.00
27	1,648,877.00	1,353,153.00	1,607,634.00	254,481.00	-30,395.00
28	1,618,895.00	1,340,307.00	1,593,431.00	253,124.00	-31,789.00
29	1,595,438.00	1,318,695.00	1,581,416.00	262,721.00	-31,922.00
30	1,559,842.00	1,305,574.00	1,573,275.00	267,701.00	-30,950.00
31	1,505,520.00	1,293,630.00	1,539,545.00	245,915.00	-33,738.00
32	1,476,160.00	1,272,796.00	1,513,032.00	240,236.00	-34,318.00
33	1,446,313.00	1,246,537.00	1,505,149.00	258,611.00	-32,913.00

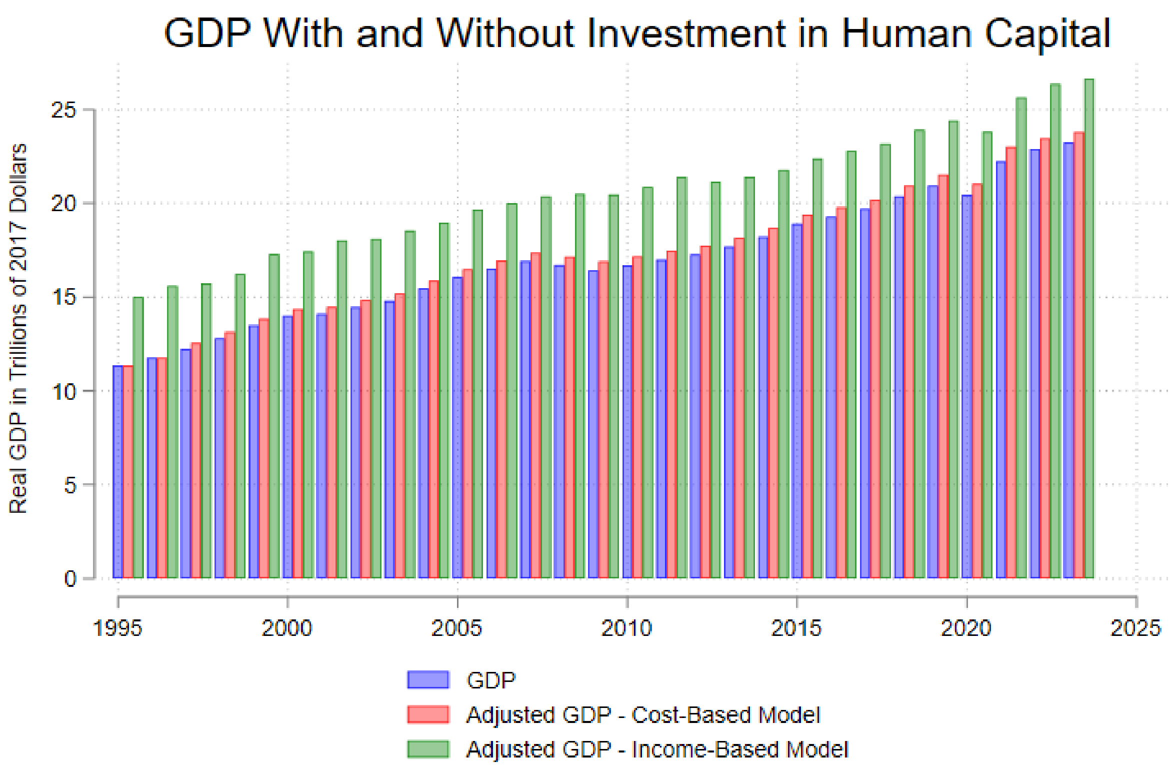
Notes. The table lists the expected future earnings paths for males of varying ages who have 12 years of completed education. The first column details lifetime earnings for those who are currently enrolled in the 13th year of education, and the second column lists the same measurement for their counterparts who are not enrolled in additional education. The third column lists lifetime earnings for those in an enrollment experiment who gain two years of vocational training. The fourth column details the gain in lifetime earnings for the otherwise unenrolled men that the vocational experiment produced, and the fifth column lists foregone wages from additional enrollment and fewer hours worked. Calculations are in Real inflation-adjusted 2017 dollars.

Figure 3. Enrollment Rates, Hours, Wages, and Relative Education Wage Premiums



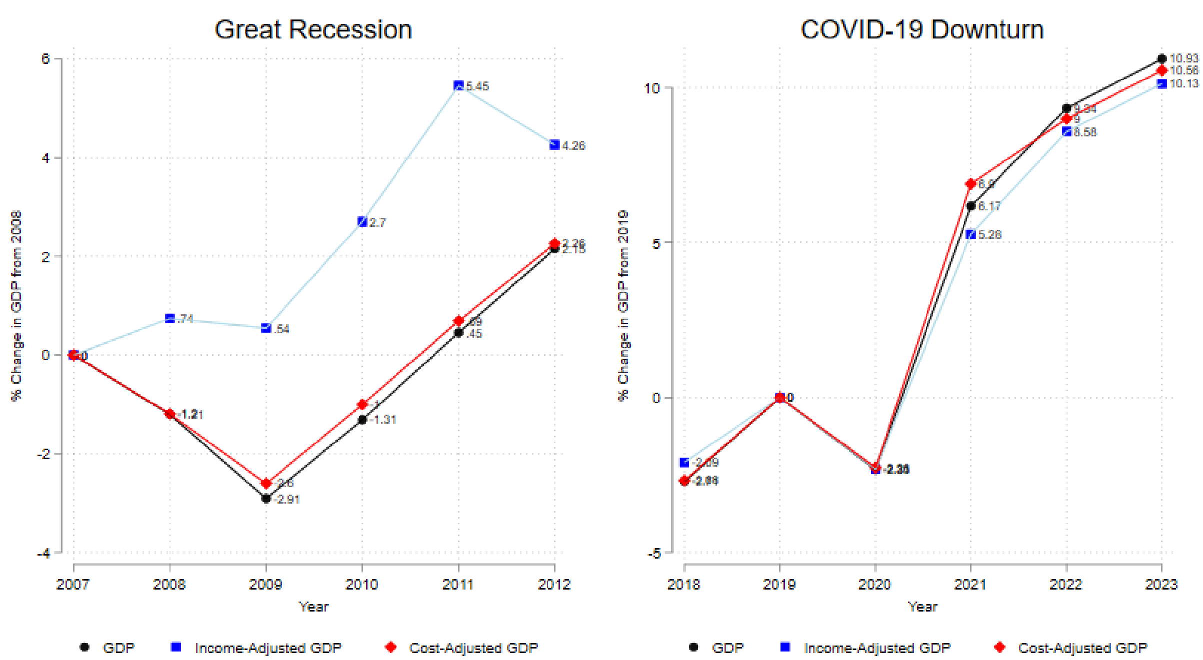
Note: I plot the enrollment rate, mean hours worked, mean hourly wages, and the mean wage ratio for 18–34-year-olds in the CPS sample between 1997 and 2023 to shed light on underlying data trends that may be impacting the income-based measure of human capital investment.

Figure 4. Baseline Real GDP, and Real GDP Incorporating Human Capital Investment



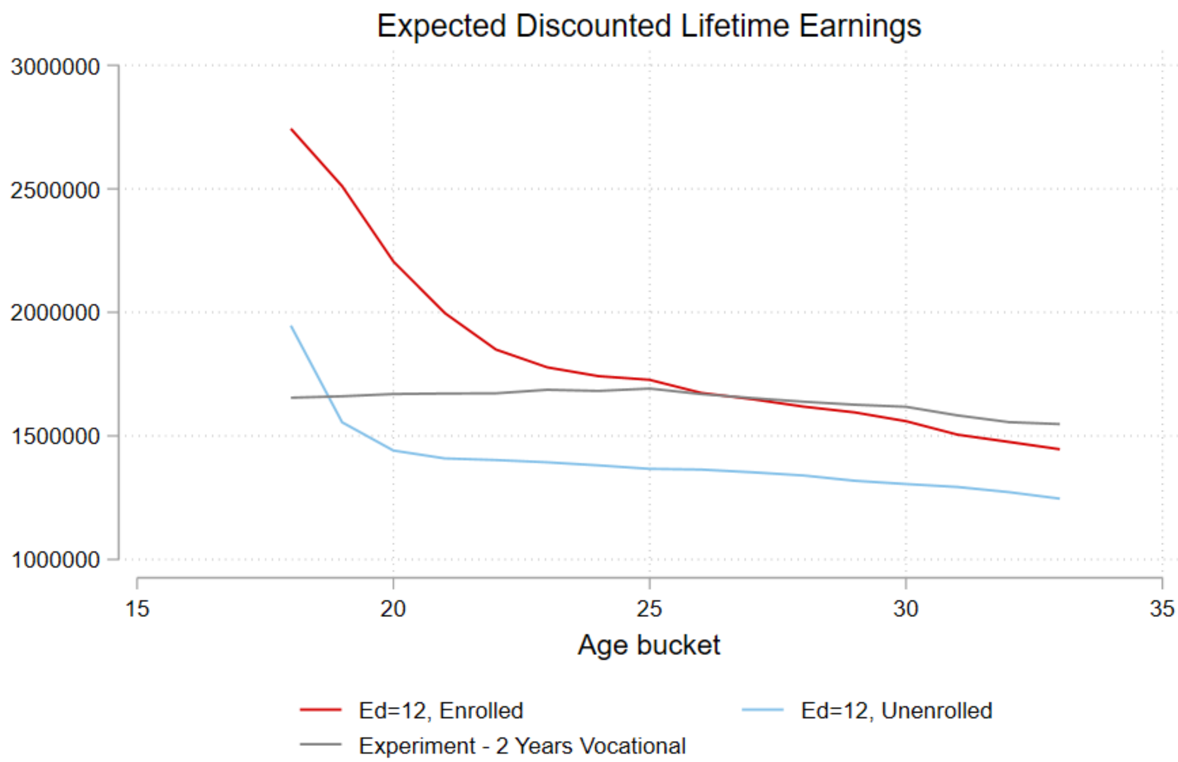
Note: The bar graph plots unadjusted GDP, and GDP adjusted with cost-based and income-based human capital measurements to illustrate how accounting for human capital can change the level of GDP.

Figure 5. Growth in Real GDP During Recent Recessions



Note: The line graph on the left plots the percentage growth in GDP over a 2007 GDP baseline during the Great Recession for unadjusted GDP and GDP adjusted with cost-based and income-based human capital. The graph on the right does the same, plotting growth over a 2019 baseline for unadjusted and human-capital augmented GDP.

Figure 6. Nominal Lifetime Earnings for Males with 12 Years of Education



Note: The graph plots the discounted future earnings for males with 12 years of completed education who are not currently enrolled in additional education by age. Also plotted are discounted future earnings for males of varying ages with 12 years of completed education who are currently enrolled in the 13th year of education. The third line plots expected lifetime earnings for males who completed 12 years of education who were mechanically enrolled in 2-year programs but then forced to exit education.

Table 8. Sensitivity Analysis: Changing Income-Based Model's Parameters and Dynamics

Year:	1995	2000	2005	2010	2015	2018	2019	2020	2021	2022	2023	Growth
Base Model	100	100	100	100	100	100	100	100	100	100	100	.75%
Investment Estimate Relative Magnitude to Baseline												
Panel A: Changing Discount Rate Parameter												
Discount = 2%	114.5	97.34	96.01	106.3	94.62	93.97	91.02	90.47	97.54	101.4	101.9	.34%
Discount = 10%	53.73	62.64	62.6	57.93	62.58	63.17	63.97	64.8	62.39	60.98	60.63	1.19%
Discount = 20%	23.11	30.39	30.26	27.48	30.47	31.14	31.47	32.23	30.83	29.99	29.77	1.67%
Panel B: Hold Input Data Constant at 1995 Levels												
Hold Pop Constant, Demog Bucket Shares Vary	100	94.33	89.87	85.82	82.73	81.03	80.54	79.86	79.81	79.35	78.69	-.1%
Hold Demog Bucket Shares Constant, Pop Grows	100	99.78	103.0	103.2	103.6	104.4	105.1	104.7	108.0	106.5	107.1	1%
Hold Pop and Demog Bucket Constant	100	94.12	92.64	88.62	85.75	84.62	84.66	83.68	86.21	84.54	84.35	.14%
Hold Enrollment Constant	100	101.9	99.99	89.03	106.1	108.9	109.1	111.9	107.0	104.1	102.6	.85%
Hold Wages Constant	100	92.12	88.73	91.66	87.32	81.82	81.21	79.46	80.78	79.55	81.51	.02%
Hold Hours Constant	100	115.7	117.5	117.1	117.4	116.5	117.6	120.1	119.3	118.7	122.1	1.48%
Hold Survival Rate Constant	100	99.09	98.98	98.40	98.56	98.76	98.79	100.1	100.7	100.3	99.71	.74%

Notes. The table lists how using different assumptions within the context of the income-based human capital model changes estimates, relative to baseline estimates. All numbers are percentages of the baseline estimate (the main model) in the same year. The baseline model's relative level is therefore set to 100 percent of itself. Growth rates are the real annualized growth rate in the level of human capital investment under each model between 1995 and 2023, with 1995 as the baseline. The growth rates do not reflect the growth rate in the percentage amounts across columns.

A. Net Investment and Price Shift Methods of Measuring Investment in Human Capital

The net investment method from Christian (2010) defines net investment due to education by aging the population up a year, taking the population out of their current age- and education- buckets and putting them in their next bucket. This approach, which is dependent on a change in population, can be transformed into a different method of measuring returns to education that focuses on the change in per capita market human capital.

This per capita approach advances education and age, which changes per capita market human capital. The method holds the year's count of enrolled individuals in bucket $\{y, s, a, e\}$ constant and then compares future wage streams of those 1 year older that obtain an additional year of education and those 1 year older that do not obtain more information. Conceptually, the current cohort of enrolled students will advance their education over the course of the current year, and by the end of the year will be a year older and have an additional year of education to boost their human capital. I refer to this as the "price-shift" or "p-shift" method.

I will explain how the net investment approach can be converted into the p-shift approach. In the net investment framework, each bucket $\{y, s, a, e\}$ undergoes its current population aging out, and the population from the less educated bucket a year younger aging in. This is a shift from both educational progression and aging, which is used to calculate net aging.

$$\begin{aligned} NetInvEd_{y,s,a,e} = & [(-SR_{y,s,a,e} * erate_{y,s,a,e} * pop_{y,s,a,e}) \\ & + (SR_{y,s,a-1,e-1} * erate_{y,s,a-1,e-1} * pop_{y,s,a-1,e-1})] * PCMHC_{y,s,a,e} \end{aligned}$$

Each bucket also has an unenrolled portion aging in. This is the shift from aging only, without education, and this is what is used to calculate the impact of aging.

$$\begin{aligned} NetInvAge_{y,s,a,e} =& [(-SR_{y,s,a,e} * (1 - erate_{y,s,a,e}) * pop_{y,s,a,e}) \\ & + (SR_{y,s,a-1,e} * (1 - erate_{y,s,a-1,e}) * pop_{y,s,a-1,e})] * PCMHC_{y,s,a,e} \end{aligned}$$

The action here is due to unenrolled students aging out of one age and ed bucket and into the next.

The above considers movements at the $\{y, s, a, e\}$ *bucket* perspective, which has individuals aging out and progressing out by education, but I now shift to examining the cohort's perspective. A cohort of enrolled or unenrolled people are aging out of one age and education bucket ($\{y, s, a, e\}$), and aging into a different age and education bucket $\{y, s, a+1, e+1\}$. That is, within the net investment framework, the cohort is having the following total impact across buckets in the calculation process:

$$\begin{aligned} ImpactEdPlusAging_{y,s,a,e} =& (-SR_{y,s,a,e} * erate_{y,s,a,e} * pop_{y,s,a,e}) * PCMHC_{y,s,a,e} \\ & + (SR_{y,s,a,e} * erate_{y,s,a,e} * pop_{y,s,a,e}) * PCMHC_{y,s,a+1,e+1} \\ =& (SR_{y,s,a,e} * erate_{y,s,a,e} * pop_{y,s,a,e}) * (PCMHC_{y,s,a+1,e+1} - PCMHC_{y,s,a,e}) \end{aligned}$$

Each surviving, enrolled individual in the bucket is having an impact on net investment (in the form of aging and getting education) equal to $(PCMHC_{y,s,a+1,e+1} - PCMHC_{y,s,a,e})$.

Alternatively, unenrolled students are only aging, so their individual contributions are:

$$\begin{aligned} ImpactAging_{y,s,a,e} =& (-SR_{y,s,a,e} * erate_{y,s,a,e} * pop_{y,s,a,e}) * PCMHC_{y,s,a,e} \\ & + (SR_{y,s,a,e} * (1 - erate_{y,s,a,e}) * pop_{y,s,a,e}) * PCMHC_{y,s,a+1,e} \\ =& (SR_{y,s,a,e} * (1 - erate_{y,s,a,e}) * pop_{y,s,a,e}) * (PCMHC_{y,s,a+1,e} - PCMHC_{y,s,a,e}) \end{aligned}$$

Each surviving, unenrolled individual in the bucket is having an impact on net investment (in the form of aging but no education) of $(PCMHC_{y,s,a+1,e} - PCMHC_{y,s,a,e})$.

One may think that enrolled people should theoretically experience an impact of aging on their career earnings about equal to the unenrolled people. So under this assumption, at the individual level, the impact of education after adjusting for aging will be:

$$\begin{aligned} EdImpact_{y,s,a,e} =& ImpactEdPlusAging - ImpactAging \\ =& (PCMHC_{y,s,a+1,e+1} - PCMHC_{y,s,a,e}) - (PCMHC_{y,s,a+1,e} - PCMHC_{y,s,a,e}) \\ =& PCMHC_{y,s,a+1,e+1} - PCMHC_{y,s,a+1,e} \end{aligned}$$

This is the difference between the income streams of two groups a year older; one with a year more education, one without.

This "p-shift" method indirectly measures the return to education, which may be more intuitive to explain and understand than the net investment method. The quantity-based net investment approach mechanically ages the population and advances it through the education system based on enrollment rates. The price-shift approach looks at the predicted gains to lifetime earnings from education.

$$\begin{aligned} Invest_y = \sum_a \sum_s \sum_e (PCMHC_{y,s,a+1,e+1} - PCMHC_{y,s,a+1,e}) \\ * (erate_{y,s,a,e} * pcount_{y,s,a,e}) * (1 - DeathRate_{y,s,a,e}) \end{aligned}$$

The term $(PCMHC_{y,s,a+1,e+1} - PCMHC_{y,s,a+1,e})$ involves comparing the per capita future wage paths of those a year older who receive more education to those a year older who do not receive an additional year of education. The comparison of these often very different groups introduces familiar selection and ability bias present in the micro education literature. Most enrolled students in each year of education are "on track," for example, most of those who just attained 6 years of education are 12 years old. To obtain an estimate of the amount that 6th grade adds to discounted expected lifetime earnings, the method above compares 12-year-olds who just completed their 6th year of education with 12-year-olds who are a year behind, having just completed their 5th year of education. Comparing "on-track" groups with groups that have fallen behind introduces ability bias; the measured difference in future earnings streams is likely due to myriad factors correlated to selection into additional educational attainment.[29]

To obtain a better counterfactual than comparing "on-track" students with students that have fallen behind a year, I compute investment using a counterfactual, as outlined in Christian (2010) and Christian (2014).

[29] This method also relies on comparisons between students who have fallen one year behind to those who have fallen two years behind, and between students who are ahead one year and those who are "on track," but these patterns are less likely than the fraction of the population who are "on track," meaning these comparisons are weighted relatively less.

$$Invest_y^{CF} = \sum_a \sum_s \sum_e (PCMHC_{y,s,a+1,e+1} - PCMHC_{y,s,a+1,e}^{CF})$$
$$* (erate_{y,s,a,e} * pcount_{y,s,a,e}) * (1 - DeathRate_{y,s,a,e})$$

In this approach, I measure investment in education by comparing results from 1.) a model where the effects of survival, aging, and education take place over each year, and 2.) a model where survival and aging occur in the absence of education. The difference between the two models appears in the school-enrolled portion of the population between ages 5 and 34, who are aging and obtaining education in each corresponding year. In the model without education, enrolled individuals are instead "frozen" and don't obtain the year of education, however they are given future enrollment probabilities of those a year younger, as if they had continued to be "on track." I then compare the discounted future earnings stream of the counterfactual group ($PCMHC_{y,s,a+1,e}^{CF}$) to the earnings stream under the scenario where the group obtains the year of education ($PCMHC_{y,s,a+1,e+1}$).

A key assumption here is that the path of enrollment probabilities of those "on track" and those "off track" are meaningfully correlated with the confounding factors present in the naive comparison between the two groups, and that removing differences in the path of enrollment probabilities mitigates the confounding factors.

A.0.1. The Jorgenson-Fraumeni Model In Action

To illustrate how the Jorgenson-Fraumeni income-based framework is working, Figure 7 plots the future expected lifetime wages based on wage profiles of the male population in 2019. This figure presents wage profiles calculated without temporal discounting in order to represent the true average future earnings for the purpose of illustration. The lifetime earnings profiles are constructed by taking a "snapshot" in 2019 of the population's wages, survival rates, and school enrollment rates by age, sex, and education attainment. I've plotted future expected lifetime earnings by age on the x-axis, with different scatter plot paths for levels of education between 12 (completed high school) to 18 (advanced professional degree). Future expected lifetime earnings are decreasing with age; as workers get older, their careers shorten, leading to lower estimates of future wages.

Notice that future earnings decrease quickly for males with 12 years of education between ages 18 and 21. This is due to future expectations for an 18-year-old with 12 years of education being quite different from those of a 21-year-old with 12 years of education. The 18-year-old has graduated high school on time, and has a relatively high probability of enrolling in another year of education after high school, and after that completing college. This on-track 18-year-old's future expected lifetime earnings is a weighted expectation of wage paths of a high school educated worker and a college educated worker; the weights associated with these future paths are determined by enrollment probabilities. In contrast, a 19-year-old with 12 years of education is off-track educationally; this group of young men didn't enroll in college straight out of high school. Their future expected lifetime wages are still a weighted average of those a year older with a high school education and those a year older with a year of college, but the weights are the enrollment probabilities which are more heavily weighted to the wage path that doesn't receive more education. This pattern continues for 20- and 21-year-olds with 12 years of education; their expected future wage paths have probabilistically converged to those of older men with only high school attainment.

This p-shift method is better for examining returns to education at more disaggregate levels. In the net investment framework, the net number of students aging into a bucket can be negative, producing a negative investment that is difficult to interpret. These same cohorts are aging into either an older or older and more educated group, which usually results in a net positive shift in population lifetime earnings. The p-shift method allows comparison between expected lifetime earnings paths with more and less education at any age or education level, which is more intuitive for discussion at a micro level.

Young males with higher educational attainment have higher estimates of future wages, as more education is associated with both higher wages and is associated with future enrollment leading to additional educational attainment. Most post-secondary educational attainment occurs from age 18 to 30, so future lifetime earnings past age 30 are less impacted by enrollment probabilities. My application of the Jorgenson-Fraumeni model, by construction, does not allow educational attainment past age 34.

B. Estimates of the Stock of Human Capital

The National Accounts calculate Fixed Asset Accounts for non-human capital types, like equipment, structures, and firms' intellectual property products. The accounts detail the stock of each type of capital at the start of the year and provide measurements of gross investment and depreciation, which are combined to calculate the stock at the end of the year in a perpetual inventory framework. Similarly, I can use the income-based method to calculate the stock of human capital each year to extend the boundary of the Fixed Asset Accounts.

B.1. Stock from the Cost-Based Model

C. Components of Cost-Based and Income-Based Investment

C.1. Composition of Cost-Based Estimates

Table 9 and Figure 8 outline the level of spending and sources of spending associated with the cost-based method of measuring human capital. Table 9 reveals that direct and indirect investments in education were about $600 billion ($0.6 trillion) in 1994, increasing to about $2.5 trillion in 2023. Direct spending made up about two thirds of the total estimates, and indirect spending in the form of time costs of students and parents makes up about one-third of the investment under this framework. Figure 8 demonstrates that all forms of investment under the cost-based framework are increasing over time. Government spending on education and student time costs make up the largest components of educational investment under the cost-based model. Student time costs as measured by forgone wages is the second largest contributor to cost-based investment.[30]

[30]Here it is important to note there is volatility in the measured CPS wages in 2021 which causes some of the jaggedness in the valuation of student time. The value of student time grows from $573 billion in 2020 to $793 billion in 2021, after which it falls to $608 billion in 2022.

Tables 10 and 11 detail the student time costs that go into the cost-based estimates, broken down by education level and sex and age and sex, respectively.

C.2. Composition of Income-Based Investment

Figure 9 plots investment in human capital under the income-based method. Investment under this framework is the incremental amount that the present value of future lifetime earnings increases due to enrollment and progression in education during each year. The top graph holds per capita market human capital constant, and mechanically advances the enrolled population through the year of education obtained during each year (this is the net investment approach). Years 0–8 of educational attainment have more students advancing out of them than advancing into them during each year, so the investment is negative. Years 9–12, 13–15 and 17–18 all have net positive students that advance through them during each year and are positive. Under this method of calculating investment, college year attainment makes up the bulk of investment.

The lower half of Figure 9 holds enrollment constant and compares the per capita market human capital of students that obtain the current year's education with a simulated version of the dataset where the enrolled students are "frozen" for the year of education but continue their education paths once unfrozen. Once again, the bulk of investment is from enrollment in college years 13–16.

Tables 12, 15, detail investment in human capital in 2019, broken down by education level and sex or by age and sex. Table 15 suggests that individuals progressing through college and post-graduate degrees are driving the majority of net investment in human capital under the net investment framework. There are more individuals aging out of primary school and those very young individuals who are aging into primary school don't receive education during the year where it is counted as investment, so primary school investment is negative. Table 14 details the change in lifetime earnings for individuals enrolled in each level of education using the "p-shift" approach described previously. Again, college and post-graduate education years add the most to expected lifetime income. In both Tables 15 and 14, male students have higher expected lifetime income, and thus have higher measurements of human capital investment.

Table 12, and 13 detail investment in human capital in 2019, disaggregated by age group and sex. In

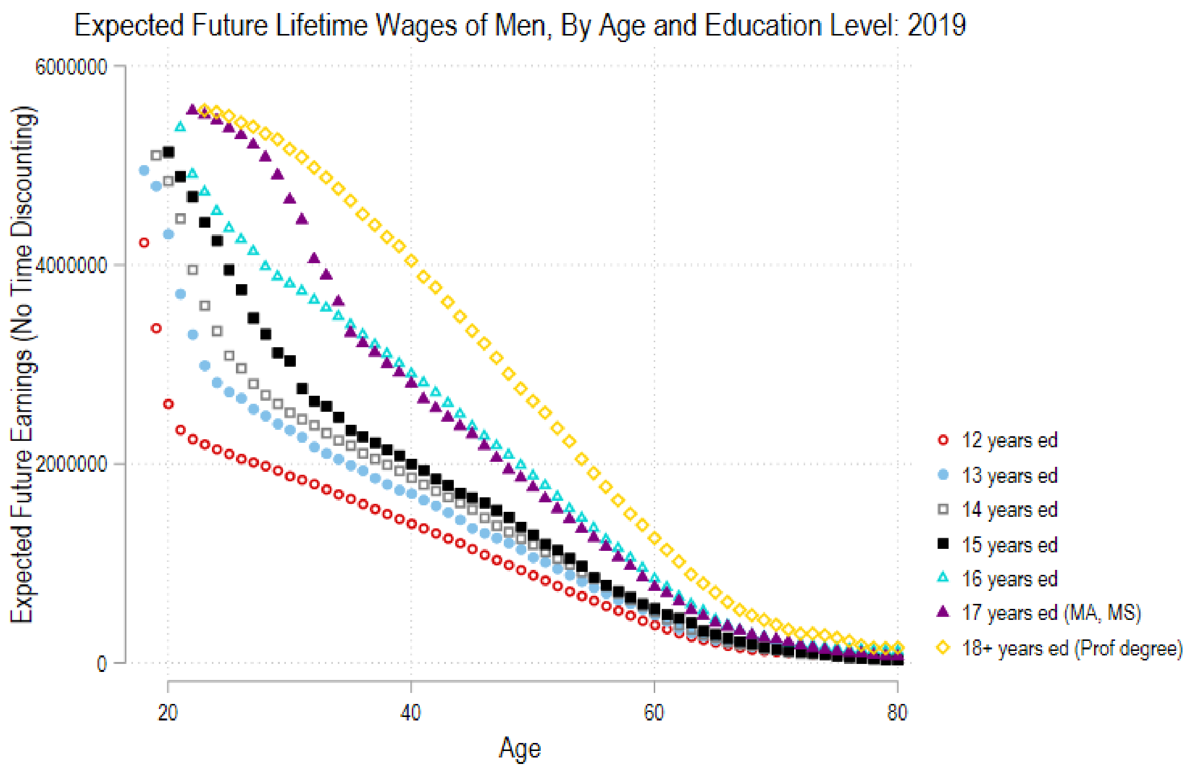
Table 13, the age group 5–9 has negative net educational progression, since those who are aging into the age bucket have zero education during the year by definition. Total investment under the net investment method is mostly driven by those ages 15–19 and ages 20–24. Table 12 utilizes the p-shift method, and finds that those aged 15–19 and 20–24 contribute the most to rising human capital investment, but those who obtain education in the ages of 25–29 and 30–34 have high per capita education effects.

D. Human Capital Compared to Physical Capital

Figure 10 illustrates gross investment spending on physical and intangible capital from BEA's Fixed Asset Accounts. Physical capital categories include public and private spending on equipment, structures, residential structures, and inventories. Intangible capital includes public and private spending on intellectual property products (IPP), namely software and research and development. Somewhat similar to measurements of nominal investment in human capital over time, gross spending on physical and intangible capital is less than $2 trillion in the early 1990s, rising to about $6 trillion in 2023. Private investment makes up the majority of investment in physical and intangible capital.

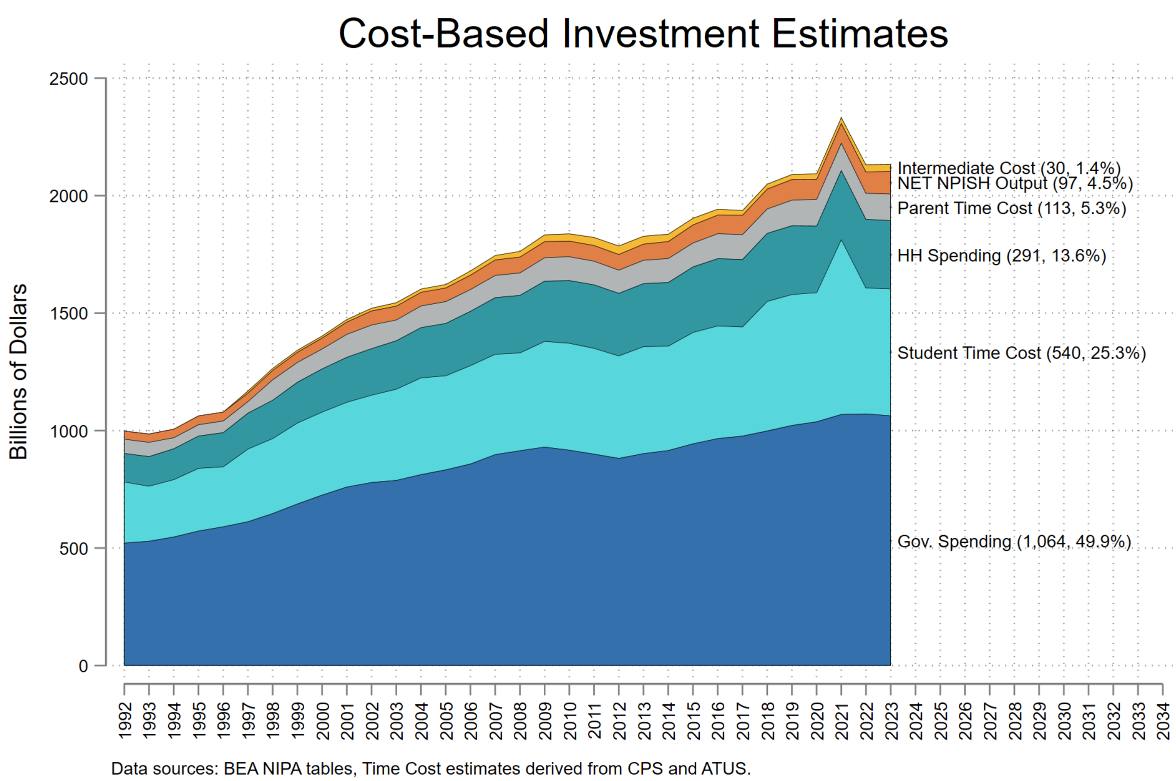
Table 16 lists investment in human capital in comparison to gross investment in physical and intangible capital already present in the national accounts. The upper part of the table details gross investment in billions of nominal dollars for each class of capital; the lower part of the table lists gross investment as a percentage fraction of human-capital adjusted GDP.

Figure 7. Future Expected Lifetime Wages By Education Level, Males, 2019



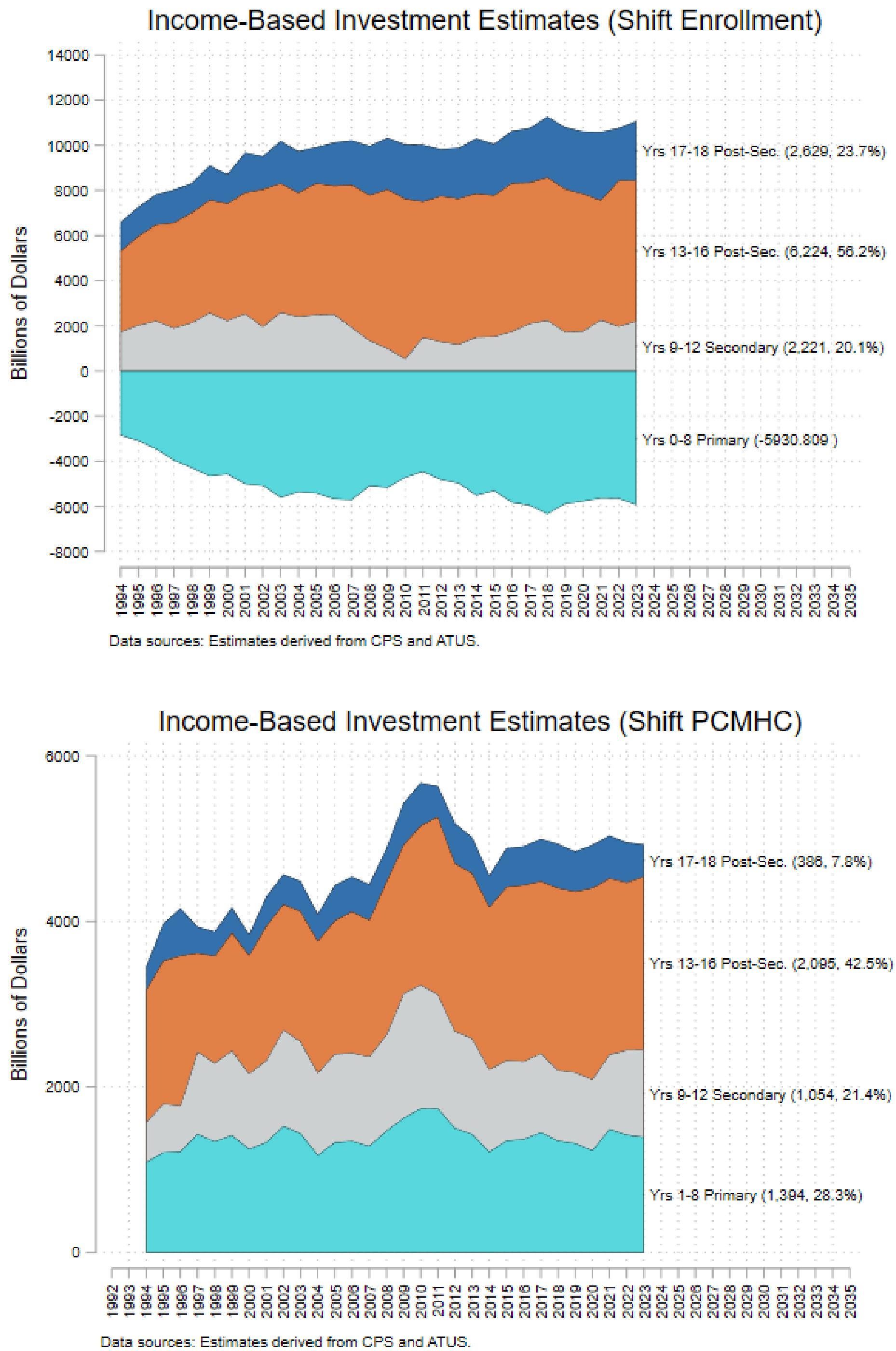
Note: The graph plots expected future lifetime earnings paths by age for males between ages 18 and 80 who have varying levels of education. Young men's future earnings paths drop quickly as selection into higher levels of education occur.

Figure 8. Cost-Based Estimates of Investment in Human Capital and Sources



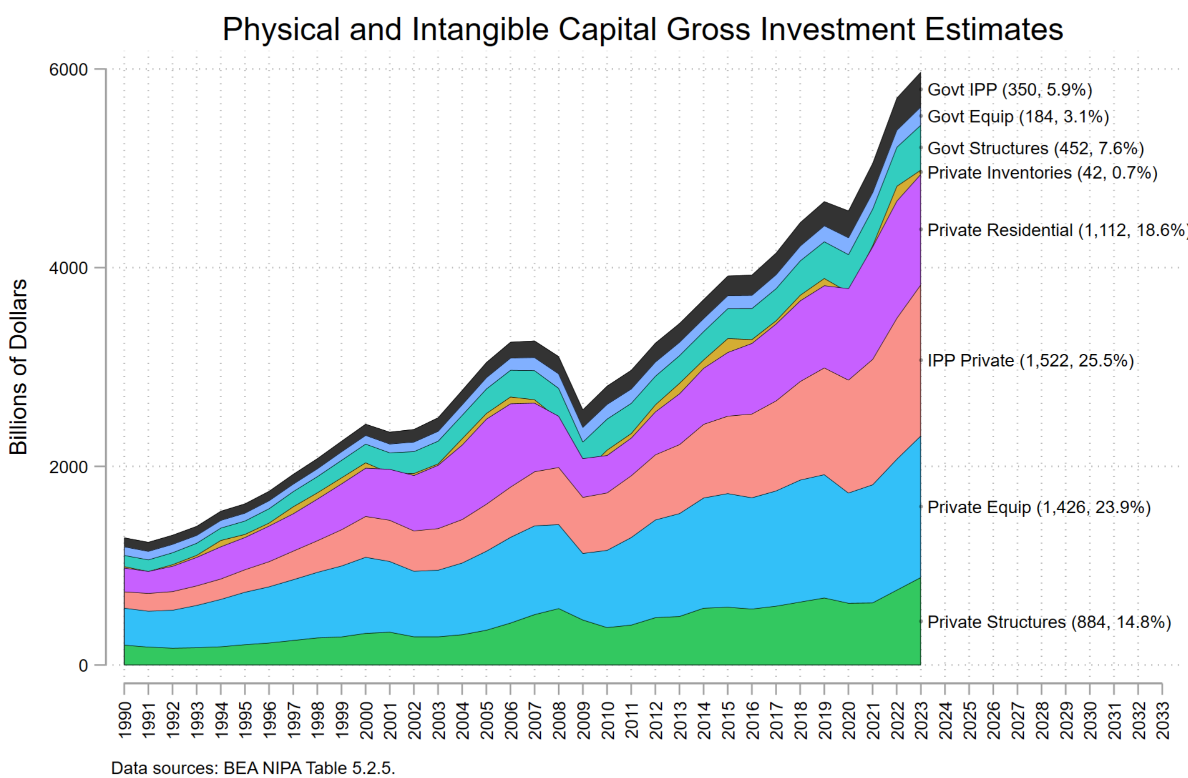
Note: The stream graph details how the levels of spending that make up inputs into the cost-based model evolve over time and contribute to aggregate cost-based investment.

Figure 9. Income-Based Estimates of Investment in Human Capital



Note: The upper graph plots income-based investment estimates by education group. Investment is calculated using net aging through education levels, so estimates of investment for the 0–8 years of education are negative, as more enrolled children age out of this category by gaining education than those who advance into grades in this group by progressing through education. For example, young 4-year-old kids advance into this group only by aging and not by acquiring education, but most 8th-graders advance out of this group by progressing to 9th grade, causing a negative aging and education effect for this group due to mechanical aging and enrollment shifts.

Figure 10. Gross Investment in Physical and Intangible Capital



Note: The graph plots sources of physical and intangible capital investment accounted for in the System of National Accounts. Capital includes equipment, structures, and intellectual property products (IPP).

Table 9. Estimates from Cost-Based Approach to Measuring Human Capital

Year:	1995	2000	2005	2010	2015	2018	2019	2020	2021	2022	2023
Household Education Spending	92.3	134.3	180.5	240.3	270	293.5	300.8	296.1	313.2	331.8	346.7
Net NPISH Spending	25.28	34.17	46.94	59.85	74.12	85.8200	90.27	88.22	89.34	103.44	115.17
Government Education Spending	385.7	531.9	676.7	827.6	914.800	1013.2	1052.1	1084.1	1139.4	1217.6	1269.5
Reclassified Intermediate Spending	0	.01	.02	.67	.42	.29	.29	.49	.44	.70	.56
Total Direct Spending	503.28	700.38	904.16	1128.42	1259.34	1392.81	1443.46	1468.92	1542.38	1653.54	1731.93
Value of Student Time	179.49	258.71	324.76	410.41	458.91	558.940	573.050	573.79	793.54	608.51	644.26
Value of Parent Time	32.5	62.18	75.59	91.5700	98.94	105.32	112.17	118.92	124.04	125.67	135.24
Total Indirect Spending	211.98	320.89	400.36	501.98	557.85	664.26	685.21	692.71	917.58	734.180	779.51
Total Cost-Based Spending	715.26	1021.27	1304.52	1630.4	1817.2	2057.07	2128.67	2161.63	2459.96	2387.72	2511.44

Notes. The table provides a detailed accounting of the estimates that impact the calculation of cost-based human capital investment. All spending numbers in billions of US dollars.

Table 10. Cost-Based Indirect Investment By Educational Attainment and Sex

Sex	Both Sexes Combined			Male Students			Female Students		
Cost-Based Model: Time Cost by Demographics									
Ed Group	Time Cost (Dollars)	Enrolled (Millions)	Total Time Inv ($ Millions)	Time Cost (Dollars)	Enrolled (Millions)	Total Time ($ Millions)	Time Cost (Dollars)	Enrolled (Millions)	Total Time ($Millions)
Primary: 0-8 Years Attained	21,663.00	33.50	725,756.62	15,093.00	17.24	260,246.78	30,033.00	16.26	488,307.41
Secondary: 9-11 Years Attained	15,943.00	12.61	201,099.52	16,340.00	6.43	105,093.24	15,527.00	6.18	95,984.92
Secondary: 12 Years Attained	8,785.00	4.63	40,692.60	7,859.00	2.38	18,691.68	9,763.00	2.25	22,000.92
Tertiary:13-15 Years Attained	11,810.00	10.25	121,101.20	12,046.00	4.71	56,792.52	11,609.00	5.54	64,308.68
Tertiary: 16 Years Attained	4,656.00	2.23	10,359.58	4,552.00	1.01	4,598.40	4,742.00	1.22	5,761.18
Post-Grad: Masters, Doctoral, Professional	7,973.00	1.92	15,273.25	9,040.00	0.77	6,915.43	7,264.00	1.15	8,357.82
All Ed Attainment, Years 1-18	6,443.00	65.14	419,689.03	6,277.00	32.54	204,269.34	6,608.00	32.60	215,419.67

Notes. The table details the time costs of studying for students enrolled in different levels of education. Dollars are adjusted for inflation using PCE are in 2017 dollars. Columns display the mean value of time dedicated to educational attainment during the 2019, the number of enrolled students in millions, and the total time investment in millions of dollars. The mean time cost per capita spent on education decreases as the age bucket increases, as enrollment rates are lower for older age groups.

Table 11. Cost-Based Indirect Investment By Age and Sex

Sex	Both Sexes Combined			Male Students			Female Students		
Cost-Based Model: Time Cost by Demographics									
Age Group	Time Cost (Dollars)	Enrolled (Millions)	Total Time Inv ($ Millions)	Time Cost (Dollars)	Enrolled (Millions)	Total Time ($ Millions)	Time Cost (Dollars)	Enrolled (Millions)	Total Time ($ Millions)
Ages 5 - 9	0.00	11.41	0.00	0.00	5.91	0.00	0.00	5.50	0.00
Ages 10 - 14	0.00	20.70	0.00	0.00	10.52	0.00	0.00	10.18	0.00
Ages 15 - 19	14,950.00	19.76	295,403.31	14,584.00	10.01	145,974.72	15,326.00	9.75	149,428.56
Ages 20 - 24	11,344.00	9.71	110,185.30	11,363.00	4.55	51,736.81	11,327.00	5.16	58,448.50
Ages 25 - 29	4,846.00	2.43	11,790.32	5,171.00	1.07	5,541.12	4,590.00	1.36	6,249.19
Ages 30 - 34	2,368.00	0.98	2,310.10	2,335.00	0.43	1,016.68	2,395.00	0.54	1,293.42
All Ages 5 - 34	12,764.00	32.88	419,689.03	12,712.00	16.07	204,269.33	12,814.00	16.81	215,419.69

Notes. Dollars are adjusted for inflation using PCE are in 2017 dollars. Columns display the mean value of time dedicated to educational attainment during the 2019, the number of enrolled students in millions, and the total time investment in millions of dollars. The mean time cost per capita spent on education decreases as the age bucket increases, as enrollment rates are lower for older age groups.

Table 12. Income-Based Investment By Age and Sex: 2019, Ages 5-34, P-Shift Approach

Sex	Both Sexes Combined			Male Students			Female Students		
Income-Based Model: Shift in PCMHC, Hold Enrolled Count Constant									
Age Group	Incremental Shift in PCMHC (Dollars)	Enrolled Count (Millions)	Total Investment ($ Millions)	Incremental Shift in PCMHC (Dollars)	Enrolled Count (Millions)	Total Investment ($ Millions)	Incremental Shift in PCMHC (Dollars)	Enrolled Count (Millions)	Total Investment ($ Millions)
Ages 5 - 9	52,689.00	11.41	584,737.64	54,753.00	5.91	314,580.71	50,474.00	5.50	270,156.93
Ages 10 - 14	34,147.00	20.70	687,281.28	32,839.00	10.52	335,933.34	35,498.00	10.18	351,347.95
Ages 15 - 19	56,752.00	19.76	1,090,328.25	57,931.00	10.01	563,784.10	55,543.00	9.75	526,544.15
Ages 20 - 24	180,014.00	9.71	1,700,120.48	211,066.00	4.55	934,415.35	152,615.00	5.16	765,705.13
Ages 25 - 29	256,818.00	2.43	607,597.52	311,250.00	1.07	324,323.76	213,975.00	1.36	283,273.76
Ages 30 - 34	279,738.00	1.12	305,127.66	324,951.00	0.48	151,303.08	246,062.00	0.64	153,824.58
All Ages 5 - 34	78,550.00	65.14	4,975,192.83	82,939.00	32.54	2,624,340.33	74,168.00	32.60	2,350,852.50

Notes. The table details the change in lifetime earnings from comparing those of the same age who have more education with those who have a year less. Dollars are adjusted for inflation using PCE are in 2017 dollars. Columns display the time-discounted, incremental expected return to lifetime earnings from a year of education obtained in the corresponding age group in 2019. Enrollment columns display the count of enrolled students in the age group bin in millions of enrolled students. The Total Investment Columns detail the total investment from the p-shift method, equal to incremental increase in PCMHC times enrolled for each group.

Table 13. Income-Based Investment By Age and Sex: 2019, Ages 5-34 Aging, Q-Shift Approach

Sex	Both Sexes Combined			Male Students			Female Students		
Income-Based Model: Hold PCMHC Constant, Shift Enrolled Population									
Age Group	Mean PCMHC (Dollars)	Shift in Enrolled Pop (Millions)	Total Investment ($ Millions)	Mean PCMHC (Dollars)	Shift in Enrolled Pop (Millions)	Total Investment ($ Millions)	Mean PCMHC (Dollars)	Shift in Enrolled Pop (Millions)	Total Investment ($ Millions)
Ages 5 - 9	1,602,961.00	-4.15	-6,658,022.50	1,879,349.00	-2.10	-3,938,667.50	1,310,406.00	-2.06	-2,696,576.00
Ages 10 - 14	1,709,040.00	0.04	62,617.61	2,007,216.00	-0.00	-1,587.48	1,399,697.00	0.04	52,390.56
Ages 15 - 19	1,854,807.00	1.38	2,556,437.25	2,170,509.00	0.78	1,682,606.25	1,536,076.00	0.60	926,352.31
Ages 20 - 24	2,070,320.00	1.90	3,936,213.50	2,525,323.00	0.97	2,455,058.00	1,685,315.00	0.93	1,565,797.50
Ages 25 - 29	1,944,304.00	0.53	1,033,725.50	2,423,397.00	0.20	487,895.97	1,505,261.00	0.33	497,249.78
Ages 30 - 34	1,659,599.00	0.31	507,397.06	2,192,963.00	0.15	324,199.00	1,271,731.00	0.16	200,804.56
All Ages 5 - 34	1,774,581.00	0.00	4,908,382.50	2,093,727.00	0.00	2,856,751.50	1,455,344.00	0.00	2,051,631.00

Notes. The table details the change in lifetime earnings from mechanically advancing the enrolled population into higher age and education groups. Dollars are adjusted for inflation using PCE are in 2017 dollars. Columns display the mean per-capita market human capital for the average person in each age group in 2019. The shift in enrollment population columns detail the net number of enrolled students aging out of (negative net enrollment) or into (positive net enrollment) each age group. The Total Investment is equal to the sum of the product of each year/sex/age/ed buckets net aging out of and into education times the corresponding PCMHC.

Table 14. Income-Based Investment By Educational Attainment and Sex: 2019, Ed years 0-18, P-Shift Approach

Sex	Both Sexes Combined			Male Students			Female Students		
Income-Based Model: Shift in PCMHC, Hold Enrolled Count Constant									
Ed Group	Incremental Shift in PCMHC (Dollars)	Enrolled Count (Millions)	Total Investment ($ Millions)	Incremental Shift in PCMHC (Dollars)	Enrolled Count (Millions)	Total Investment ($ Millions)	Incremental Shift in PCMHC (Dollars)	Enrolled Count (Millions)	Total Investment ($ Millions)
Primary: 0-8 Years Attained	37,954.00	33.50	1,271,544.94	37,792.00	17.24	651,645.28	38,127.00	16.26	619,899.67
Secondary: 9-11 Years Attained	36,845.00	12.61	464,742.39	35,348.00	6.43	227,351.22	38,403.00	6.18	237,391.17
Secondary: 12 Years Attained	49,467.00	4.63	229,135.77	49,335.00	2.38	117,343.44	49,607.00	2.25	111,792.33
Tertiary:13-15 Years Attained	199,821.00	10.25	2,048,966.43	245,108.00	4.71	1,155,604.43	161,275.00	5.54	893,362.00
Tertiary: 16 Years Attained	127,445.00	2.23	283,582.34	151,845.00	1.01	153,380.57	107,160.00	1.22	130,201.77
Post-Grad: Masters, Doctoral, Professional	281,610.00	1.92	539,451.14	322,024.00	0.77	246,343.85	254,740.00	1.15	293,107.29
All Ed Attainment, Years 1-18	74,259.00	65.14	4,837,423.02	78,409.00	32.54	2,551,668.79	70,117.00	32.60	2,285,754.23

Notes. The table details the change in lifetime earnings from comparing those of the same age who have more education with those who have a year less. Dollars are adjusted for inflation using PCE are in 2017 dollars. Columns display the time-discounted, incremental expected return to lifetime earnings from a year of education obtained in the corresponding age group in 2019. Enrollment columns display the count of enrolled students in the age group bin in millions of enrolled students. The Total Investment Columns detail the total investment from the p-shift method, equal to incremental increase in PCMHC times enrolled for each group.

Table 15. Income-Based Investment By Educational Attainment and Sex: 2019, Ed Years 0-18 Progressing, Q-Shift Approach

Sex	Both Sexes Combined			Male Students			Female Students		
Income-Based Model: Hold PCMHC Constant, Shift Enrolled Population									
Ed Group	Mean PCMHC (Dollars)	Shift in Enrolled Pop (Millions)	Total Investment ($ Millions)	Mean PCMHC (Dollars)	Shift in Enrolled Pop (Millions)	Total Investment ($ Millions)	Mean PCMHC (Dollars)	Shift in Enrolled Pop (Millions)	Total Investment ($ Millions)
Primary: 0-8 Years Attained	1,648,193.00	-4.08	-5,887,120.88	1,931,907.00	-2.05	-3,453,130.44	1,348,969.00	-2.03	-2,433,990.44
Secondary: 9-11 Years Attained	1,826,128.00	-0.55	-859,322.94	2,136,471.00	-0.33	-572,099.29	1,498,362.00	-0.22	-287,223.65
Secondary: 12 Years Attained	1,685,885.00	0.97	2,599,709.61	2,041,148.00	0.76	1,941,217.98	1,404,257.00	0.21	658,491.64
Tertiary:13-15 Years Attained	2,073,078.00	1.43	3,318,922.08	2,537,713.00	0.61	1,771,406.85	1,668,234.00	0.83	1,547,515.23
Tertiary: 16 Years Attained	2,288,097.00	1.26	3,016,054.68	2,929,368.00	0.62	1,795,649.04	1,860,234.00	0.64	1,220,405.64
Post-Grad: Masters, Doctoral, Professional	2,728,411.00	0.96	2,720,140.12	3,378,715.00	0.39	1,373,707.53	2,192,290.00	0.58	1,346,432.59
All Ed Attainment, Years 1-18	1,774,581.00	0.00	4,908,382.50	2,093,727.00	0.00	2,856,751.50	1,455,344.00	0.00	2,051,631.00

Notes. The table details the change in lifetime earnings from mechanically advancing the enrolled population into higher age and education groups. Dollars are adjusted for inflation using PCE are in 2017 dollars. Dollars are adjusted for inflation using PCE are in 2017 dollars. Columns display the mean per-capita market human capital for the average person in each age group in 2019. The shift in enrollment population columns detail the net number of enrolled students aging out of (negative net enrollment) or into (positive net enrollment) each age group. The Total Investment is equal to the sum of the product of each year/sex/age/ed buckets net aging out of and into education times the corresponding PCMHC.

Table 16. Investment Estimates for Human Capital, Physical and Intangible Capital

Year:	1995	2000	2005	2010	2015	2018	2019	2020	2021	2022	2023	Growth
Investment in Human Capital, Billions of Dollars												
Investment (Cost-Based)	1125.66	1477.98	1701.99	1915	1986.78	2157.59	2199.78	2199.86	2483.89	2226.09	2231.94	2.47%
Investment (Income-Based P-Shift)	6515.14	5441.83	5488.7	6315.29	5099.81	5073.61	4973.21	4925.79	4892.40	4549.08	4400.51	-1.39%
Investment (Income-Based Q-Shift)	6198.11	5640.6	5547.64	5889.17	4900.95	4867.87	4772.46	4631.56	4648.08	4492.43	4310.95	-1.29%
Equipment	643.560	872.2	921.74	947.48	1265.4	1356.91	1375.91	1254.63	1343.11	1456.23	1563.73	3.22%
Structures	404.43	571.85	647.62	712.25	869.190	944.38	1001.21	945.58	930.21	1058.83	1212.47	4%
IPP	366.64	565.96	661.47	782.22	982.33	1224.32	1311.36	1394.89	1538.21	1703.75	1815.19	5.88%
Private Residential	481.93	663.050	1055.36	417.6	661.2	800.88	804.22	881.85	1063.41	1037.98	931.550	2.38%
Total Physical and Intangible	1896.57	2673.06	3286.19	2859.56	3778.11	4326.49	4492.69	4476.95	4874.94	5256.79	5522.93	3.89%
Investment in Human Capital as Percentage of HC-Adjusted GDP												
Investment (Cost-Based)	9.91%	10.3%	10.33%	11.17%	10.26%	10.31%	10.23%	10.47%	10.81%	9.5%	9.39%	
Investment (Income-Based P-Shift)	38.28%	29.71%	27.09%	29.31%	22.68%	21.28%	20.49%	20.76%	19.27%	17.66%	16.96%	
Investment (Income-Based Q-Shift)	37.11%	30.46%	27.3%	27.89%	21.99%	20.59%	19.82%	19.76%	18.48%	17.48%	16.68%	
Equipment	5.66%	6.08%	5.60%	5.53%	6.53%	6.48%	6.4%	5.97%	5.84%	6.21%	6.58%	
Structures	3.56%	3.98%	3.93%	4.15%	4.49%	4.51%	4.66%	4.5%	4.05%	4.52%	5.10%	
IPP	3.23%	3.94%	4.02%	4.56%	5.07%	5.85%	6.10%	6.64%	6.69%	7.27%	7.640%	
Private Residential	4.24%	4.62%	6.41%	2.44%	3.41%	3.83%	3.74%	4.2%	4.63%	4.43%	3.92%	
Total Physical and Intangible	16.69%	18.62%	19.95%	16.68%	19.51%	20.67%	20.9%	21.31%	21.21%	22.43%	23.23%	

Notes. All spending numbers in billions of US dollars.

Table 17. Stocks of Human Capital and Other Capital

Year:	1995	2000	2005	2010	2015	2018	2019	2020	2021	2022	2023	Growth
Human Capital, Billions of Dollars												
Stock, Human Capital	122688.	199155.	239772.	269652.	313605.	355858.	370936.	362944.	374769.	400278.	423340.	4.52%
Stock, Human Capital, Change p, g	56211.5	93650.4	110695.	121459.	142943.	163029.	170262.	167986.	176152.	190554.	201208.	4.66%
Stock, Human Capital with Constant Pop	145717.	216083.	243912.	258148.	295422.	327966.	339414.	329979.	347511.	373576	391397.	3.59%
Stock, Human Capital with Constant Pop, Change p, g	66843.5	101332.	113048.	117592.	134262.	148886.	154340.	150561.	159453.	171731.	179525.	3.59%
Net Investment, Human Capital Stock	2945.99	2916.82	3612.79	5135.29	4781.31	5214.3	5260.51	5368.29	5548.67	5867.16	6264.71	2.73%
Net Investment by Population Change Category, Billions of Dollars												
Investment from Deaths	-273.65	-426.63	-545.1	-592.18	-751.26	-893.56	-913.23	-1043.4	-1179.1	-1194.8	-1177.4	5.35%
Investment from Population Aging	-3678.0	-4927.7	-5773.7	-6891.8	-7319.9	-8229.3	-8479.9	-8448.7	-9117.8	-10244.	-10855.	3.94%
Investment from Population Aging - Adults	-3927.3	-5328.5	-6264.9	-7433.1	-7952.5	-8920.6	-9195.9	-9157.5	-9784.5	-10901.	-11544.	3.93%
Investment from Population Aging - Toddlers	249.3	400.76	491.23	541.28	632.680	691.35	715.96	708.86	666.71	657.23	689.71	3.7%
Investment from Population Education	2802.63	3023.36	3651.59	4788.8	4594.87	5002.85	5048.17	5047.62	5271.58	5794.09	6137.21	2.84%
Investment from Births	2201.98	3379.29	4104.71	4307.65	4914.03	5257.13	5191.90	5113.27	5126.37	5158.37	5386.75	3.25%
Investment from Residual (Migration)	478.59	988.420	-46.37	-844.42	457.97	819.37	1521.1	-1834.3	4299.23	3769.49	508.66	.22%
Total Net Investment	1531.54	2036.7	1391.09	767.96	1895.69	1956.48	2368.01	-1165.5	4400.19	3282.64	0	-39.01%

Notes. All spending numbers in billions of US dollars. Human capital stock is calculated through the J-F income-based model, and is equal to the present value of expected future income in each year, given the lifetime income paths constructed from all older groups during that year. The second row has results from the J-F model using more conservative assumptions for the wage growth rate of (0% annual growth above the wages of those in older groups rather than the baseline 2%) and for the temporal discount rate (assuming a more myopic rate of 7% rather than the baseline 4%). The third row has results from the J-F model using the mean population count and enrollment rates across all years, holding population and enrolled population constant. The fourth row has results from the J-F model using the mean population and enrollment counts across all years, and using more conservative assumptions for the wage growth and temporal discounting. The total net investment in human capital in 2023 is 0 by construction due to lack of 2024 measures.