Net Investment and Stocks of Human Capital in the United States, 1975-2013

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Abstract

This article continues the research initiated in Christian (2010, 2014) on measurement of human capital stocks and investment in the United States. It develops estimates of a series of human capital stock and net investment from 1975 to 2013, using the lifetime earnings approach of Jorgenson and Fraumeni (1989, 1992). The series decomposes net investment into investment from births, investment in education net of aging of persons enrolled in school, depreciation from aging of persons not enrolled in school, depreciation from deaths, and a residual term that includes net migration and measurement error. The study also discusses the cost-based approach of measurement in human capital of Kendrick (1976) and compares investment in education between the cost and income approaches. The stock of human capital rose at an annual rate of 1.0 per cent between 1977 and 2013, with population growth as the primary driver of human capital growth. Per capita human capital remained much the same over this period, with the effect of greater levels of education being offset by the effect of an aging population.

Accounting for human capital continues to be one of the liveliest topics in national accounts. The stock of human capital measures the long-term productive capacity of a population or workforce. Activities that add to this stock, such as education, are identified as investment in human capital, and are valued at the extent to which they increase the human capital stock. Boarini *et al.* (2012) identify several reasons for persistent interest in human capital, including as an avenue to a more complete understanding of productivity and economic growth, as a broader measure of capital for assessing the sustainability of economic development, as an alternative approach to measuring the output and productivity of the education sector, and as an indicator of overall economic well-being.[2]

This study continues the research of Christian (2010, 2014) and develops estimates of a series of human capital from 1975 to 2013 using the income-based approach of Jorgenson and Fraumeni (1989, 1992). The estimates include

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2 Liu and Fraumeni (2014) review conceptual and practical aspects of human capital and its prospective employment in national accounts.

human capital embodied in persons of all ages, including children, persons of working age, and persons of retirement age, whether currently in the labour force or not. The primary data set used in producing the estimates is the March demographic and October school enrollment supplements of the Current Population Survey. The stock of human capital rose at an annual rate of 1.0 per cent between 1977 and 2013, with the effect of greater levels of education, which increases the stream of earnings produced over the remaining lifetime of the existing population, being offset by the effect of an aging population, which reduces this stream of earnings. Per capita human capital remained much the same over this period, with the effect of greater levels of education being offset by the effect of an aging population. While net investment in education rose annually by 1.0 per cent per year, net investment in human capital as a whole declined between 1977 and 2013, with depreciation from aging increasing substantially over this period. The series presented includes both a market component based on lifetime market earnings (which is what is used to measure the above growth rates), as well as a non-market component based on lifetime non-market production. It also breaks out "active" human capital, which is comprised of persons of working age and older, separately from "nascent" human capital, which is comprised of children younger than working age.

The study also discusses the cost method of human capital, most commonly associated with Kendrick (1976). It compares income-based and cost-based estimates of investment in education, with the former typically being about three times greater than the latter. Interestingly, when GDP is measured using income-based measures of investment in education as an alternative to the cost-based consumption measures in the official GDP estimates, the extent of the decline in GDP in the Great Recession is mitigated by a modest degree.

The two sections that immediately follow briefly discuss alternative approaches to human capital measurement and review recent efforts in measurement of human capital. The main results of the study are in the section entitled "Updated and Extended Income-Based Measures of Human Capital for the United States". This section presents new measures of human capital in the United States from 1975 to 2013 using a method based on the income-based approach of Jorgenson and Fraumeni (1989, 1992). The last three sections discuss cost-based approaches to human capital, illustrate the implications of human capital investment measures for education with respect to the Great Recession, and present possibilities for future research.

Methods for Measuring Human Capital

Human capital can be measured in several different ways. The most commonly applied method is the lifetime income approach of Jorgenson and Fraumeni (1989, 1992). The lifetime income approach measures the stock of human capital using an estimate of the lifetime earnings in present discounted value of all persons in a population. Net investment in human capital is measured as the impact of events that either increase (births, education, immigration) or reduce (deaths, aging, emigration) the total lifetime income of a population. The Jorgenson-Fraumeni model requires data on population, average earnings, and school enrollment rates by age, sex, and education, as well as data on survival rates by age and sex. It also requires specifying a real per capita income growth rate, which makes it possible to project average earnings into the future, and a discount rate, which makes it possible to combine current and projected future earnings into a single measure of lifetime income in present discounted value. While the original Jorgenson-Fraumeni paper measured both a market and non-market component to human capital, most applications of human capital focus only on the market component.

An alternative to the lifetime income approach is the cost approach (Kendrick, 1976). This approach measures investment in human capital by the cost of producing it. Kendrick includes in human capital investment the costs of rearing children to working age, education and training, health and safety (although only in part, attributing the other part to maintenance), and job search, hiring, migration, and other costs associated with labour mobility. From accumulated investment over time, appropriately depreciated, a stock of human capital can be measured. Recent applications of the cost approach, such as Kokkinen (2011) and Gu and Wong (2015), have focused on the cost of education. A cost-based measure of human capital, based on per capita accumulated educational expenditure, is a component of the Index of Economic Well-Being produced by the Center for the Study of Living Standards (CSLS) (Osberg and Sharpe, 2011).

A third approach is the indicators approach, which measures human capital using an indicator or group of indicators, such as average years of schooling or literacy rate (OECD, 1998). A fourth approach is the indirect approach, which is employed by the World Bank (2011). This approach measures intangible capital, which is equal to the difference between a country's future consumption stream in present discounted value and the value of its physical capital and natural capital. Intangible capital includes human capital and social/institutional capital.

Recent Research in Human Capital

The OECD Human Capital Project

One of the most ambitious recent projects in human capital is the Human Capital Project of the Organization for Economic Co-operation and Development (OECD) (Liu, 2014). It measures the stock of human capital over time between 1997 and 2007 in 16 countries, including the United States, with the years covered differing from country to country by data availability. The approach used is the lifetime income approach of Jorgenson and Fraumeni (1989, 1992), which will be henceforth described simply as Jorgenson-Fraumeni. While the original Jorgenson-Fraumeni papers (and this study) measure a version of the human capital stock that includes all persons, including children, the OECD project focuses specifically on human capital embodied in persons of working age, defined as persons ages 15 to 64. This is referred to by Li *et al.* (2010) as "active" human capital.

Country-specific Studies in Human Capital

Recent studies that measure human capital for individual countries have overwhelmingly employed the lifetime income approach. These include studies for Argentina (Coremberg, 2010); Australia (Wei, 2004, 2008); Canada (Gu and Wong, 2010, 2015); China (Li *et al.*, 2010); India (Gundimenda *et al.*, 2006); Mexico (Coremberg, 2015); the Netherlands (Rensman, 2013); New Zealand (Le, Gibson, and Oxley, 2006); Norway (Liu and Greaker, 2009); Sweden (Ahlroth, Bjorklund, and Forslund, 1997); the United Kingdom (Jones and Chiripanhura, 2010); and the United States (Christian, 2010, 2014).

Some individual country studies employ the cost method, such as Kokkinen's (2011) study for Finland and Gu and Wong's (2015) study for

Canada. Both of these studies focused on investment in education. Gu and Wong (2015) measured investment in education in Canada using both the lifetime-income and the cost method for comparison, and compared real growth in educational investment over the 1975-2005 period between the two approaches.

In 2013, the United Nations Economic Commission for Europe (UNECE) established a Task Force on Measuring Human Capital with the purpose of creating guidelines and best practices for countries to establish satellite accounts for human capital. This task force produced a guide that was published in December 2016 (United Nations Economic Commission for Europe, 2016).

Updated and Extended Income-Based Measures of Human Capital for the United States

Using data from the Current Population Survey, I have updated and extended the human capital series in Christian (2010, 2014) to cover the 39 year period between 1975 and 2013. The extended series includes both market and nonmarket components, and both nominal and real measures. This series makes it possible to identify longer-term trends in human capital that cover multiple generations. It also overlaps with the original lifetime-income-based human capital measures of Jorgenson and Fraumeni.

Method

The lifetime income approach of measuring human capital, developed by Jorgenson and Fraumeni, measures the stock of human capital as equal to the total lifetime income in present discounted value of a population. The approach begins by measuring average lifetime income by year, age, sex, and level of education, which is done by starting at the oldest (or topcoded) age in the population for which human capital is measured and working backwards. In the results presented in this article, age is topcoded at 80. Lifetime income at age 80 and older is equal to:

$$i_{y,s,80+,e} = [1-(1+\rho)^{-1}(1+g)sr_{y,s,81+}]^{-1} yi_{y,s,80+,e}$$

where

$i_{y,s,a,e}$ = lifetime income in year y of persons of sex s, age a, and years of education e

$yi_{y,s,a,e}$ = yearly income in year y of persons of sex s, age a, and years of education e

$sr_{y,s,a}$ = survival rate in year y of persons of sex s from age a-1 to age a

ρ = discount rate

g = income growth rate

The above equation is the sum of an infinite series equal to expected lifetime income in present discounted value of a person who has an annual probability of survival of $sr_{y,s,a}$, who conditional on survival receives an income that starts at $yi_{y,s,80+,e}$ and grows at a rate of g each year, and who discounts future earnings at an annual rate of ρ. This is different from the original Jorgenson-Fraumeni papers, which set lifetime income to zero for people at the maximum measured age, but it is an appropriate and inclusive adaptation given that people at age 80 or older do earn income.

At all other ages, lifetime income is equal to:

$$i_{y,s,a,e} = yi_{y,s,a,e} + (1+\rho)^{-1}(1+g)sr_{y,s,a+1} \times \left[senr_{y,s,a,e}\, i_{y,s,a+1,e+1} + (1-senr_{y,s,a,e})\, i_{y,s,a+1,e} \right]$$

where

$senr_{y,s,a,e}$ = school enrollment rate in year y of persons of sex s, age a, and years of education e.

This is the sum of yearly income and the present discounted value of expected lifetime income one year later. The second term on the right-hand-side of the above equation is equal to current lifetime income of people one year older, adjusted for discounting, income growth, probability of survival, and probability of increasing educational attainment. This approach projects income in the future by age, sex, and level of education using income in the present, multiplied by an income growth rate. It also projects school enrollment in the future using school enrollment in the present. In the model used in this article, the probability of school enrollment is assumed to be zero for persons younger than 5 or older than 34. In addition, yearly income is assumed to be zero for persons younger than 15. This was the case in the original Jorgenson-Fraumeni papers as well, except that (consistent with Census definitions at the time) persons were able to earn income at age 14.

The approach described above is used to compute lifetime market income and lifetime non-market income. Yearly market income is set to average pre-tax wage, salary, and self-employment earnings by age, sex, and education. This is different from the original Jorgenson-Fraumeni approach, which used post-tax compensation; however, given that human capital is ultimately a measure of the productive capacity of a population, pre-tax earnings, which measure the value of labour to producers of goods and services, is the more appropriate measure. An even more appropriate measure of yearly income may be pre-tax compensation, which would include the value of benefits and employer contributions to social security. These aspects of compensation are difficult to capture using the data set used in this study, the Current Population Survey. However, one could approximate the extent to which human capital is undermeasured by the use of earnings alone by using the overall, economy-wide ratio of wages, salaries, and self-employment income to total labour compensation.[3]

Yearly non-market income is set to the amount of time spent in household production multiplied by the average post-tax wage by age, sex, and education, where the tax rate used is the marginal tax rate. The post-tax wage is used because household production is produced by persons whose opportunity cost is equal to the value to them of additional time spent in market work. Time spent in household production is time not spent at work, in school, or in personal maintenance, which implicitly defines household production as all activities other than work, school, or personal maintenance. Time spent in school is assumed to equal 1300 hours per year for persons enrolled in school, while time spent in personal maintenance is assumed to equal 10 hours per day for all persons.

The stock of human capital (hc_y) is equal to the sum of lifetime income across all persons. This can be expressed simply as:

$$hc_y = \Sigma_s \Sigma_a \Sigma_e (pcount_{y,s,a,e} \times i_{y,s,a,e})$$

where

$pcount_{y,s,a,e}$ = population in year y of persons of sex s, age a, and years of education e.

This can be measured for market income only, for non-market income only, or for the two combined. When measuring the stock of human capital in real terms, the quantity is the population $pcount_{y,s,a,e}$ and the weight is lifetime income $i_{y,s,a,e}$. Under this approach, the volume of human capital changes with the size and distribution of the population by age, sex, and education, using lifetime income as the marginal rate of substitution across age, sex, and educa-

3 When this ratio is measured using the National Income and Product Accounts (NIPAs) of the U.S. Bureau of Economic Analysis, it increases steadily from 1.15 in 1975 to 1.21 in 1992, and remains around 1.2 since then. This is computed using Table 2.1 of the NIPAs, as the ratio of the sum of compensation and proprietor's income to the sum of wages and salaries and proprietor's income.

tion. In the results in this article, the volume of the stock of human capital is measured using a chained Fisher index, which is converted to constant 2013 dollars by multiplying by the stock's nominal value in 2013.

Changes in nominal human capital can be broken down into net investment and revaluation as follows:

$$hc_{y+1} - hc_y = \Sigma_s \Sigma_a \Sigma_e [(pcount_{y+1,s,a,e} - pcount_{y,s,a,e}) \times i_{y,s,a,e}] + \Sigma_s \Sigma_a \Sigma_e [pcount_{y+1,s,a,e} \times (i_{y+1,s,a,e} - i_{y,s,a,e})]$$

The first term on the right-hand side of the equality above is net investment: the impact of changes in the size and distribution of the population on the stock of human capital. The second term is revaluation: the change in the nominal human capital stock from switching from the old year's to the new year's measures of lifetime income.

Net investment can further be broken down into different components. In this article, net investment in human capital is broken down into five components:

a) Investment from births;

b) Investment from education net of the aging of persons enrolled in school;

c) Depreciation from aging of persons not enrolled in school;

d) Depreciation from deaths; and

e) Residual net investment from migration and measurement error.

This is different in several aspects from the original Jorgenson-Fraumeni papers' approach. One substantial difference is that investment in education is measured net of aging, rather than as gross investment as in Jorgenson and Fraumeni (1992). Investment in education is measured net of aging while in school because it is a more robust measure than a gross measure of investment in education. When investment in education is measured on a gross basis, the resulting measures are often extremely large. This is because gross investment in education is, for most persons of school age, measured as the difference between the lifetime earnings of people who are completing school on schedule and the lifetime earnings of people who are a year behind schedule. This is typically a very large difference, because students who have fallen behind have a considerably higher likelihood of dropping out of school completely. Measuring investment in education on a gross basis assumes that this difference is the return to a single year of education for everyone — the difference between lifetime trajectories with substantially different likelihoods of diploma or degree completion.

This is not necessarily an appropriate assumption, however. An alternative assumption is that people who actually attended school would, had they missed a year for exogenous reasons, just pick up where they left off a year later. Under this assumption, gross investment in education becomes much smaller (Christian, 2010). The above discussion is for a model where aging takes place before education, i.e. people enrolled in school move up one year in age and then move up one year in education. In the original Jorgenson-Fraumeni papers, education takes place before aging, which mitigates the size of gross investment, since the approach compares the lifetime incomes of people on schedule in their education with those of people one year ahead of schedule rather than one year behind it. However, the approach still compares the lifetime incomes of people on different educational trajectories and yields very large results.

Measuring investment in education net of aging does not require making quite such a strong counterfactual assumption, because it measures investment in education for enrolled persons as the total change in lifetime income from having an additional year of education and from being a year older. This is not the difference between staying on track or falling behind (or moving unusually ahead) in one's education; rather, for school-aged people, it is the difference of moving one year further along a typical course of education. As a result, it does not require making an assumption about what would happen if a person who was on the typical course of education were to exogenously deviate from it. This yields a more robust measure with a smaller magnitude.

Residual net investment is another measure used in this article but not in the original Jorgenson and Fraumeni accounts. It is net investment that cannot be attributed to births, deaths, education, or aging. It likely has two components. The first is migration: people enter and leave a country, changing both the size and distribution of the country's population by age, sex, and education. The second, however, is measurement error. The data on births, deaths, education, and population are not constrained to perfectly match each other, and any additive frictions will also be reflected in the residual net investment measure.

Investment and depreciation are measured in real terms using chained Fisher volume indices, which are converted to constant 2013 dollars by multiplying by nominal values in 2013. Real net investment is computed by subtracting the real human capital stock from the following year's real human capital stock, and residual net investment is computed by starting with real net investment, subtracting investment from births and education, and adding depreciation from deaths and aging.

Data

The primary data sets used to produce the human capital measures are, as in Christian (2010, 2014), the October and March supplements of the Current Population Survey (CPS). The October supplements from 1975 to 2014 are employed to estimate population and school enrollment in the United States by age, sex, and individual year of education. The March supplements from 1976 to 2014 are employed to estimate average number of hours worked and average hourly earnings by age, sex, and individual year of education.

Until 1991, the CPS measured educational attainment using individual years of education, with no education as the lowest measured level of education and 18 years of education as the highest. Beginning in 1992, the CPS switched its measure of educational attainment to one that emphasized degrees and credentials earned: high school diploma, some college-no degree, some college-associate's degree, bachelor's degree, master's degree, etc. In 1998, the CPS added additional questions that made it relatively easy to measure reasonably well educational attainment by individual year. From 1992 to 1997, however, it was necessary to impute the distribution by individual years of education of population, hours worked, and wages from the information about credentials earned only.

One implication of using the October CPS to compute school enrollment rates in the Jorgenson-Fraumeni models is that it is assumed that all students who are enrolled in October will complete a year of education by the end of the school year. This will lead to some overestimation of investment in education, since some students will drop out between October and the following June.

Federal and state marginal income tax rates for people in the March sample are computed using the Internet version of TAXSIM (v9), hosted at the web site of the National Bureau of Economic Research (Feenberg and Coutts, 1993). TAXSIM computes state marginal tax rates only as far back as 1977; they were imputed for 1975 and 1976 using the federal marginal tax rate and the coefficients from a regression of state marginal tax rates on federal marginal tax rates in 1977.

Table 1: Market Human Capital Stock and Net Investments in the United States, 1977 and 2013 (trillions of dollars)

	1977		2013	1977-2013
	Nominal	Real (2013$)	Nominal	Annual pct. change, real
Human capital stock	$41.1	$169.2	$239.4	1.0
Net investment in human capital	$0.4	$1.8	$1.2	-1.1
Investment from births	$0.7	$2.9	$3.5	0.5
Investment from education, net of aging	$0.6	$3.0	$4.2	1.0
Depreciation from aging, non-enrolled	$0.8	$3.5	$6.2	1.6
Depreciation from deaths	$0.1	$0.4	$0.5	0.3
Residual net investment	$0.0	$-0.2	$0.2	

Source: Author's calculations.

The population and school enrollment aggregates by year, age, sex, and educational attainment computed using the October CPS are adjusted before analysis to match reported aggregates. Population aggregates are adjusted to match January population estimates by the Bureau of the Census; estimates from January are chosen to correspond to annual measures of births and deaths based on the calendar year. The population estimates include all persons in the United States, including persons serving overseas in the Armed Forces; it is useful to note that this is different from the civilian non-institutional population (including children) universe of the CPS. School enrollments are adjusted to match elementary, secondary, and college enrollment results reported in the *Digest of Education Statistics* published by the U.S. Department of Education. The adjustments are made using a simple multiplicative factor applied to all age/sex/education groups.

Death rates by age and sex are measured using life tables from the Centers for Disease Control (CDC) and adjusted to match counts of deaths from the CDC. Births are also measured using counts from the CDC. The real per capita income growth rate is assumed to be 2 per cent per year, and the discount rate is assumed to be 4 per cent.

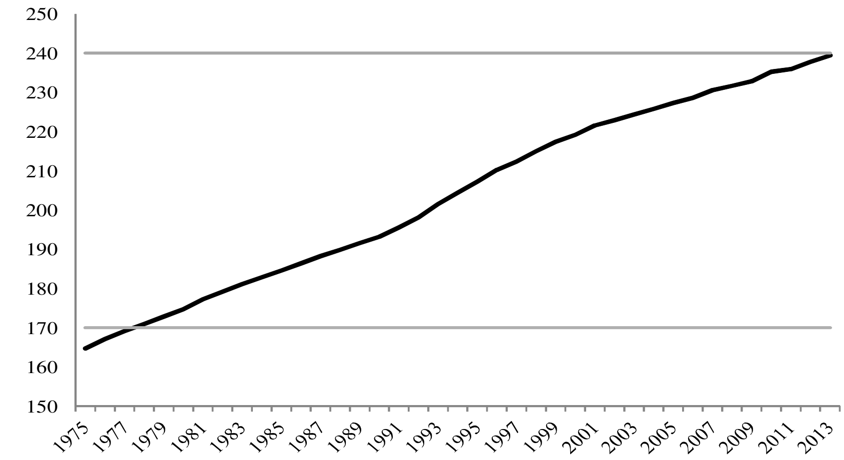
Income-based human capital measures, 1975-2013

Table 1 presents a summary of the market component of human capital using the income approach in the United States between 1977 and 2013. While the estimated series of human capital extends backward to 1975, the years 1977 and 2013 were chosen for comparison because both were at similar points in the business cycle — at an early point in recovery from a substantially large recession. The market component of human capital is presented because it is the aspect of human capital that is the focus of recent applications.

The market component of the human capital stock is about one-third of the combined market and non-market human capital stock. The proportion of the total human capital stock that is in the market component has declined steadily over the time period covered, from a peak of 33 per cent in 1977 to a low of 29 per cent in 2013.[4] As can be seen in Table 1, the market component of the human capital stock has increased at an average annual rate of 1.0 per cent between 1977

4 While the market-to-non-market ratio of the stock of human capital has declined overall, the change has been in two different directions for men and for women. Between 1977 and 2013, the proportion of the human capital stock that is in the market component declined from 41 per cent to 34 per cent among men, but increased from 20 per cent to 24 per cent among women.

Chart 1: Market Component of Stock of Human Capital in the United States,1975-2013 (trillions of constant 2013 dollars)



Source: Author's calculations.

and 2013. Net investment in human capital declined between 1977 and 2013 at an annual rate of 1.1 per cent, although, given the year-to-year volatility of the total net investment estimate (see Chart 3 below), this likely overstates the long-run downward trend. An alternative approach to measuring long-run change, which regresses log net investment on a time trend and is more robust to year-to-year volatility, measures a long-run annual rate of decline in real net human capital investment of 0.5 per cent per year.

Chart 1 presents the real stock of the market component of human capital for each year between 1975 and 2013, using a chained Fisher volume index. For the most part, the trend is of a steady rise over this period, with an acceleration during the 1990s and a slowdown in the twenty-first century.

The real stock of human capital can be straightforwardly decomposed across the size and distribution of the population by age, sex, and education if a Paasche or Laspeyres volume index is used to measure it in real terms. Since the real human capital stock is only trivially different across chained Fisher, Paasche, and Laspeyres indices, the switch to a Paasche for a decomposition of changes from year to year is a reasonable choice. Let $pcount_{y,s(y'),a(y''),e(y''')}$ be equal to the population by sex, age, and education given:

- total population at time y;
- distribution of population across sex at time y';
- distribution of population within sex and across age at time y'';
- distribution of population within sex and age and across education at time y'''.

Growth in human capital using a Paasche volume index can be decomposed as follows:

Total growth

$$= \Sigma_s \Sigma_a \Sigma_e [(pcount_{y+1,s,a,e} - pcount_{y,s,a,e}) \times i_{y+1,s,a,e}] / \Sigma_s \Sigma_a \Sigma_e (pcount_{y,s,a,e} \times i_{y+1,s,a,e})$$

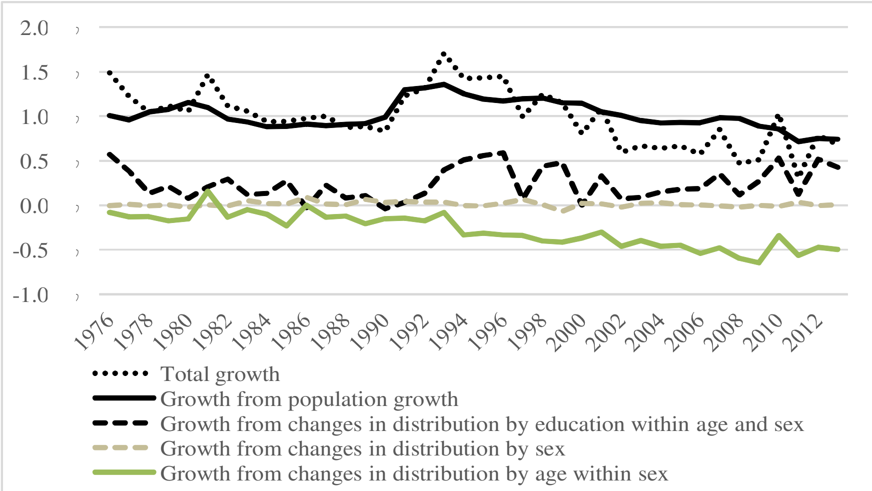
Growth from population growth

$$= \Sigma_s \Sigma_a \Sigma_e [(pcount_{y+1,s(y),a(y),e(y)} - pcount_{y,s,a,e}) \times i_{y+1,s,a,e}] / \Sigma_s \Sigma_a \Sigma_e (pcount_{y,s,a,e} \times i_{y+1,s,a,e})$$

Growth from changes in the distribution of population by sex

$$= \Sigma_s \Sigma_a \Sigma_e [(pcount_{y+1,s(y+1),a(y),e(y)} - pcount_{y+1,s(y),a(y),e(y)}) \times i_{y+1,s,a,e}] / \Sigma_s \Sigma_a \Sigma_e (pcount_{y,s,a,e} \times i_{y+1,s,a,e})$$

Chart 2: Annual Changes in the Real Market Human Capital Stock in the United States, 1976-2013, (per cent)



Source: Author's calculations.

Growth from changes in the distribution of population by age within sex

$= \Sigma_s \Sigma_a \Sigma_e [(pcount_{y+1,s(y+1),a(y+1),e(y)} - pcount_{y+1,s(y+1),a(y),e(y)}) \times i_{y+1,s,a,e}] / \Sigma_s \Sigma_a \Sigma_e (pcount_{y,s,a,e} \times i_{y+1,s,a,e})$

Growth from changes in the distribution of population by level of education within age and sex

$= \Sigma_s \Sigma_a \Sigma_e [(pcount_{y+1,s,a,e} - pcount_{y+1,s(y+1),a(y+1),e(y)}) \times i_{y+1,s,a,e}] / \Sigma_s \Sigma_a \Sigma_e (pcount_{y,s,a,e} \times i_{y+1,s,a,e})$

This decomposition does rely on a specific order in which population, sex, age, and education are approached. However, the order employed is a logical one. Population, unlike sex, age, and education, is a measure of size rather than distribution, and so it makes sense to approach it first. Sex is unlikely to be relevant at all given that its distribution does not change much over time, and so its placement is not especially relevant. Since education is substantially determined by age among persons of high school age or younger, it makes sense to decompose by age before education.

Chart 2 presents a graphical decomposition of yearly changes in human capital by population, age, sex, and education over the 1975-2013 period using the Paasche volume index decomposition described above. A more detailed accounting of changes in the stock of human capital between 1977 and 2013 is presented in Table 2. This table breaks down changes in aging and in education across three age groups: pre-working-age (14 and younger), working-age (ages 15 to 64), and post-working-age (65 and older). Given the relatively long period of time, results in Table 2 are presented using both 1977 and 2013 lifetime incomes as fixed weights.

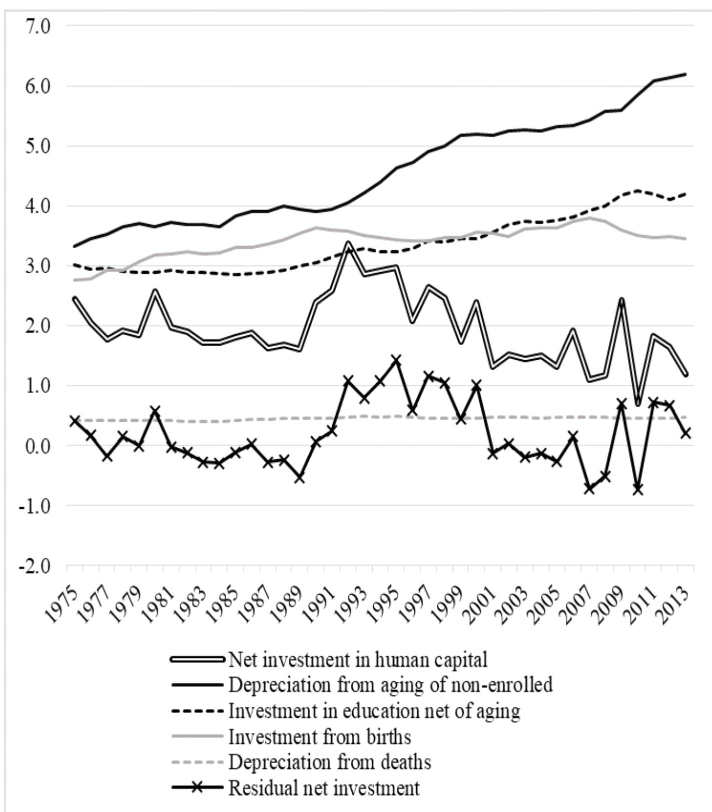
Between 1977 and 2013, the dominant driver of change in the stock of human capital was population growth. The second most important driver of change in human capital was an increase in the education level of working-age persons, which has a positive effect on human capital growth given that people with more education have higher lifetime incomes. The third most important driver was an increase in the average age of working-age persons, which has a negative effect on human capital growth given that older people have fewer working years remaining and lower lifetime incomes.The

Table 2: Decomposition of Total Growth in the Real Market Human Capital Stock in the United States, 1977-2013 (per cent change)

	1977 weights	2013 weights
Total cumulative growth	39.8	42.0
Population growth	44.0	44.0
Distribution by sex	0.9	0.5
Distribution by age within sex	-16.5	-18.2
Between age groups (0-14,15-64,65+)	-6.5	-7.3
Between children and adults (0-14,15+)	-2.0	-3.2
Between adults (15-64,65+)	-4.5	-4.2
Within age groups	-9.9	-10.9
Within children (0-14)	-0.2	-0.3
Within working-age adults (15-64)	-9.7	-10.5
Within post-working-age adults (65+)	0.0	-0.1
Distribution by level of education within age and sex	11.2	15.7
Within children (0-14)	-0.7	-0.8
Within working-age adults (15-64)	11.5	15.8
Within post-working-age adults (65+)	0.4	0.7

Source: Author's calculations.

Chart 3: Investment in Market Component of Human Capital in the United States, 1975-2013 (trillions of constant 2013 dollars)



Source: Author's calculations.

Table 3: Human Capital Stock and Investment in Education, Market and non-Market in the United States, Comparison with Jorgenson-Fraumeni, billions of current dollars.

	Human capital stock IG: 2% D: 4%		Human capital stock IG: 1.32% D: 4.58%		Investment in education IG: 1.32% D: 4.58%	
Year	Jorgenson-Fraumeni (1989)	New Series	Jorgenson-Fraumeni (1992)	New Series	Jorgenson-Fraumeni (1992)	New Series
1975	95,046	111,020	114,568	86,505	1,792.7	2,230.6
1976	103,214	119,993	121,760	93,508	1,825.5	2,505.8
1977	110,042	122,484	133,148	95,597	1,883.6	2,248.8
1978	122,024	130,473	146,260	102,049	1,991.9	2,455.2
1979	136,288	146,002	159,836	114,389	2,113.1	2,456.4
1980	142,516	157,640	171,254	123,551	2,346.6	2,579.2
1981	154,260	170,425	186,814	133,582	2,515.9	2,701.0
1982	166,990	187,872	198,951	147,107	2,834.9	3,108.5
1983	179,555	204,263	210,240	159,709	2,975.4	3,521.3
1984	193,829	215,685	225,320	168,665	3,171.2	3,829.2
1985	N/A	226,050	242,713	177,158	3,359.3	4,248.0
1986	N/A	241,262	268,567	188,764	3,779.0	4,663.8

Source: Jorgenson and Fraumeni (1989,1992); author's calculations.
Note: Results adjusted to match modeling in Jorgenson-Fraumeni as described in the text. In the column labels, IG is the income growth rate, while D is the discount rate.

impacts of education and aging have for the most part offset each other over this time period.

Chart 3 graphically presents the time series of investment in human capital from 1975 to 2013, breaking down net investment into five components: investment from births, depreciation from deaths, investment from education net of aging of persons enrolled in school, depreciation from aging of persons not enrolled in school, and residual net investment, which includes both migration and measurement error. The most apparent result is the growth of depreciation from aging since the early 1990s. The volatility of the residual component — which, in turn, creates volatility in the complete net investment measure — is likely to be a result of measurement error from measures on births, deaths, and education during the course of a year not perfectly lining up with measures of population by age, sex, and education at the beginning of the year.

Comparison to Jorgenson-Fraumeni

The new human capital series presented here extends far enough back that it can be compared to the original results of Jorgenson and Fraumeni. However, the series is different in several aspects. In order to make the results in the new series more comparable to those in the original Jorgenson-Fraumeni series, the following adjustments were made to the new series:

- Measures combine both market and non-market components of human capital;
- Investment in education is measured as gross investment, rather than net of aging of people enrolled in school;
- Market lifetime income is measured using post-tax earnings rather than pre-tax earn-

ings, where the tax rate employed is an average tax rate;

- Earnings and value of non-market time are set to zero after age 75;
- The highest level of education is set to 17 years rather than 18 years;
- Results are adjusted using a constant multiplier to reflect total compensation rather than just wages, salaries, and self-employment income;
- The income growth rate is set to 1.32 per cent and discounting is set to 4.58 per cent for comparisons with results in Jorgenson and Fraumeni (1992).

The results of the comparison are presented in Table 3. The human capital stock results from this study roughly match measures of the human capital stock in Jorgenson and Fraumeni (1989). In contrast, this study estimates a substantially lower human capital stock than Jorgenson and Fraumeni (1992), but roughly match measures of gross investment in education.[5]

Active Human Capital

Many studies of human capital, including the OECD project, focus on the human capital of people of working age only, described in Li *et al.* (2010) as "active" human capital. The logic behind measuring active human capital is that a measure of human capital should only include people who are available to work. Jones and Chiripanhura (2010) note that this mirrors the idea of measuring physical capital in a way that only includes physical capital that is currently able to be deployed in production.

Table 4 splits human capital measures between "active" human capital, which includes persons ages 15 and older, and "nascent" human capital, which includes persons ages 14 and younger.

The proportion of the human capital stock that is active has increased over time, from 70 per cent in 1977 to 73 per cent in 2013. People who are above "working age", which is often defined as people age 65 and older, are included in the measure of active human capital because the accounts presented here do take into account labour force participation by older people.

Separating investment in human capital between active and nascent human capital involves adding a new component to investment. When people turn 15 years old, they leave the nascent stock and enter the active stock. As a result, all human capital embodied in them is transferred from the nascent stock to the active stock. This transfer needs to be added as a component to net investment in both active and nascent human capital, as investment in the former and as depreciation of equal magnitude in the latter.

Over the 1975-2013 period, net investment in human capital excluding the nascent-to-active transfer is always positive in the nascent stock and is always negative in the active stock. Investment in education net of aging is always between 60 per cent to 67 per cent active and 33 per cent to 40 per cent nascent over this same period. This means that, net of aging of persons enrolled in school, investment in late secondary and post-secondary education is of greater magnitude when measured using lifetime earnings than investment in elementary and early secondary education.

Even if one regards the active human capital stock as the important stock measure, it is none-

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5 Fraumeni *et al.* (2015) compare results from 1982 in Jorgenson and Fraumeni (1989) to results from 2009 in Christian (2014) and find substantive differences in several aspects of human capital. These include: the relative magnitudes of human investment, time in household production and leisure, and gross private domestic product; of gross private national human capital formation, gross private national capital formation, and full private national consumer outlays; and of gross private national saving and human capital saving. In contrast, a comparison of results from 1982 and 2009 in the account presented here finds that the relative magnitudes of these aspects have remained relatively similar over time.

Table 4: Active and Nascent Market Human Capital in the United States, 1977 and 2013 (trillions of current dollars)

	1977		2013	
	Active	Nascent	Active	Nascent
Human capital stock	28.6	12.5	175.7	63.7
Net investment in human capital	0.6	-0.2	1.3	-0.2
Investment from births	0.0	0.7	0.0	3.5
Investment from education, net of aging	0.4	0.2	2.8	1.4
Depreciation from aging, non-enrolled	0.8	0.0	6.1	0.1
Depreciation from deaths	0.1	0.0	0.4	0.0
Residual net investment	0.0	0.1	-0.1	0.3
Transfer, nascent to active stock, age 15	1.2	-1.2	5.1	-5.1
Net investment (excluding transfer)	-0.5	1.0	-3.8	5.0

Source: Author's calculations.

theless useful to account for net investment in both the active and nascent stocks. This is because net investment in the nascent stock ultimately accumulates to the active stock as cohorts within the nascent stock reach age 15. The advantage of accounting for investments in the nascent stock is that it will better reflect the timing of the investment.

Lifetime Income

The lifetime-income approach to measuring the human capital stock uses lifetime earnings as the rate of substitution between age, sex, and education. Chart 4 illustrates lifetime earnings, measured using cross-sections from 1977 and 2013, for men and women at different ages and different levels of education.

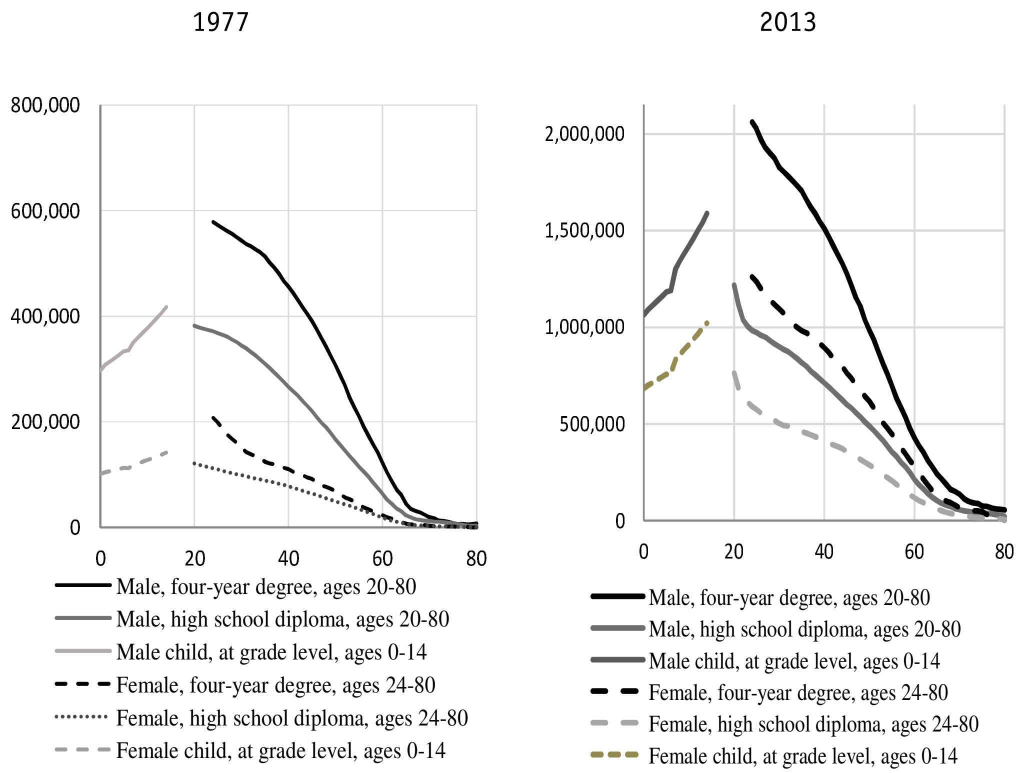
In both charts, lifetime earnings appear to decline roughly linearly between the ages of 25 and 65 for both men and women at a given level of education. The lifetime return to education is substantially higher in 2013 than in 1977, and, while men have higher measured lifetime earnings in both years, the difference between the sexes is considerably smaller in 2013. The combination of these two factors reverse the order of lifetime earnings between men with high school diplomas and women with four-year degrees; while measured lifetime earnings were greater among the former using the 1977 cross-section, they are greater among the latter in the 2013 cross-section.

Per Capita Human Capital

The per capita human capital stock captures the composition of the human capital stock by age, sex, and education, using lifetime earnings as the rate of substitution between these characteristics. Per capita human capital is one focus of cross-country comparisons in the OECD human capital project.

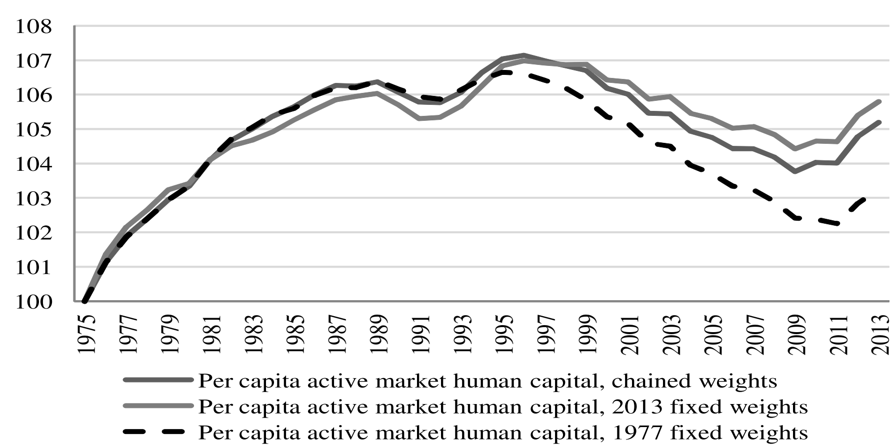
Measures of per capita human capital are most intuitive when measured using the active human capital stock per working-age person, with working age defined as ages 15 to 64. This provides a picture of the composition of the working-age population. People age 65 and older are not included in this measure, since many are

Chart 4: Lifetime Earnings by Sex, Age, and Education in the United States, 1977 and 2013,(current dollars)



Source: Author's calculations.

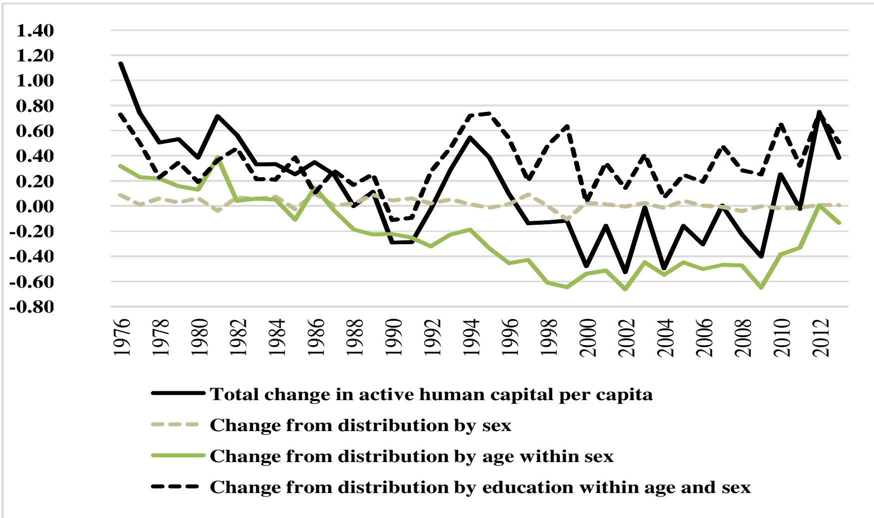
Chart 5: Per Capita Active Market Human Capital in the United States (1975 = 100)



Source: Author's calculations.

retired and purposefully do not work; including them in a measure that attempts to capture the characteristics of the working-age population would be distortionary. Since the definition of working age for the per capita measures do not include people 65 and older, lifetime earnings are computed for this particular application under the assumption that earnings are zero at age 65 and older.

Chart 6: Annual Changes in Real Per Capita Active Market Human Capital in the United States, 1976-2013 (per cent)



Source: Author's calculations.

Chart 5 presents per capita active market human capital, measured as a chained Fisher quantity index set to 100 in 1975, and alternatively as unchained, fixed-weight Paasche and Laspeyres quantity indices. Chart 6 presents year-to-year changes in per capita active human capital, decomposed into parts explained by changes in the distribution of the population by sex, by age within sex, and by level of education within age and sex, with the decomposition facilitated by using a Paasche quantity index.

The trend in per capita human capital from 1975 to 2013 depends on whether increases in the level of education of working-age people have a positive impact large enough to mitigate the negative impact from increases in the age of working-age people. Liu (2014) finds a similar pattern of aging and education having opposite effects on per capita human capital over time between the mid-1990s and the late 2000s in several countries (including the United States) in the OECD human capital project. For the most part, per capita human capital rises quickly in the late 1970s and 1980s, levels out in the 1990s, declines in the 2000s, and rises again in the early 2010s. Note that changes in per capita human capital over the 1975-2013 period differ depending on whether lifetime incomes from the late 1970s or the early 2010s are used to value it. This is likely because the return to education is considerably higher in the 2010s than in the 1970s (see, for example, the differences between college and high school lifetime earnings in Chart 4 above), since increases in the level of education are the primary positive factor contributing to changes in per capita human capital over this period.

The Stock of Human Capital Relative to GDP and to Fixed Assets

Table 5 on the next page compares the market human capital stock to other aggregates, in particular gross domestic product and the stock of fixed assets. Both total and active human capital declined relative to both aggregates between 1977 and 2013 reflecting the slower growth of the former.

Table 5: Ratio of Market Human Capital to GDP and Fixed Assets in the United States, 1977 and 2013

	Human capital to GDP	Active human capital to GDP	Human capital to fixed assets	Active human capital to fixed assets
1977	19.71	13.72	7.17	4.99
2013	14.34	10.52	4.91	3.60

Source: Author's calculations. GDP and fixed assets measures from the National Income and Product Accounts (NIPA) tables of the Bureau of Economic Analysis of the U.S. Department of Commerce.

Measuring Human Capital Using Cost

Kendrick's Cost Accounting for Human Capital

An alternative approach to accounting for human capital uses the cost of producing human capital rather than the income produced from activities that create human capital. Abraham (2010) notes that the cost and income methods are analogous, respectively, to the income and production sides of national accounts. The most widely cited example of accounting for human capital using cost is Kendrick (1976), which will henceforth be described simply as Kendrick. Kendrick defined human investment as the costs of rearing children to working age, education and training, health and safety, and labour mobility.

Kendrick's cost-based measures of the stock of human capital are substantially lower than the income-based measures of Jorgenson and Fraumeni. Jorgenson and Fraumeni (1989) directly compare them, and find that their income-based measures are typically about fifteen times greater than Kendrick's cost based measures. It is useful to note that the income-based measures in Jorgenson and Fraumeni (1989) combine a market and non-market component, including not only market earnings but also household production. However, inclusion of the non-market component of human capital is not nearly enough to account for this discrepancy.

A recent application of Kendrick's approach is Kokkinen (2011), which measured human capital investment and stock in Finland. Rather than focusing on all aspects of human capital defined by Kendrick, Kokkinen focused on human capital from formal education alone. His approach to human capital investment included only expenditures on education (specifically, in the context of Finland, government expenditures), and did not include foregone earnings. Kokkinen defines the human capital stock as only including the educational capital of persons of working age and outside of school. Under this approach, investments in education for students still enrolled in school are accumulated in an inventory, separate from the human capital stock. At the time of graduation, that accumulated educational investment is moved out of the inventory and into the human capital stock. The human capital stock, when understood this way, is an analogue in the cost method to income-based measures of active human capital. The inventory of human investment accumulated by persons still in school is an analogue to nascent human capital.

Measuring Human Capital Investment Using the Cost Method

Measuring human capital investment using the cost method requires identifying activities as human capital investment and measuring the costs of those activities. For some aspects of some activities, this can be as easy as re-classifying already existing aggregates in national

Table 6: Income- and Cost-based Measures of Investment in Formal Education in the United States,1977 and 2013 (billions of current dollars)

Year	Cost-based education investment				**Income-based education investment**	**Ratio of income and cost measures**
	Personal consumption expenditure	Government consumption expenditure	Value of time spent at school	Total cost of education		
1977	17.7	95.4	73.2	186.3	629.5	3.38
2013	259.7	752.1	412.6	1,424.4	4,193.8	2.94

Source: Author's calculations.

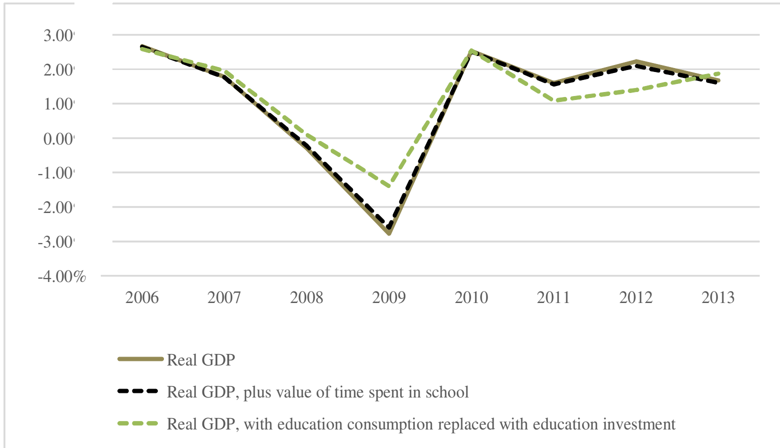
accounts from consumption to investment. For example, to measure investment in formal education, one could re-classify personal consumption expenditures for education (NIPAs Table 2.4.5) and government consumption expenditures for education (NIPAs Table 3.17) as investment. This approach excludes the rental value of capital related to education, as well as the amount of time spent in school or study by students. For other activities, measuring investment requires more effort. To continue with the previous example, suppose one would like to include the value of student time in investment in formal education. This would, at the very least, require measuring the amount of time spent by students in school, computing an appropriate wage rate at which to value that time, and then multiplying the two.

Another example would be if one wanted to exclude the research and public service function of higher education (as distinct from the instructional and student services function) from human capital investment. This would require either starting from more disaggregated data than that in the NIPAs or consulting an alternative data set such as the Integrated Postsecondary Education Data System (IPEDS) to estimate the proportion of aggregated expenditures that would need to be removed.

Ideally, measures of human capital investment that use the cost approach would cover the same activities as measures that use the income approach. Investment in education is an aspect of human capital investment in which cost approaches and income approaches substantially agree. Both value the act of schooling at the time of schooling, but in different ways—the cost approach by the cost of producing education, and the income approach by the lifetime return to education. Table 6 provides a comparison of human capital investment from formal education using these two approaches.A similar comparison for Canada is in Gu and Wong (2015).

In Table 6, the income measure of investment in education is the market component of investment in human capital from education, as presented in Table 1. The cost measure of investment in education is comprised of personal and government consumption expenditure for education from the NIPAs, plus the value of student time. To compute the value of student time, enrollment by age, sex, and education is multiplied by 1300 hours per full-time equivalent enrolled person, where part-time enrolled persons are treated as one-third of a full-time enrolled person. This yields total hours in school or study by age, sex, and education. The hourly opportunity cost of student time is measured as earnings per hour by age, sex, and education from the March Current Population Survey, multiplied by one minus the combined federal and state marginal tax rate computed by TAXSIM. This is the same post-tax wage rate used in the computation of non-market human capital earlier in this article. It is assumed to be zero for children ages 14 and younger. The total value of student time by age, sex, and education is computed as the product of total hours in

Chart 7: Annual Change in Real GDP Using Different Accounting for Education in the United States,2005-2013, (per cent)



Source: Author's calculations.

school or study multiplied by the hourly opportunity cost of student time by age, sex, and education. This is summed across age, sex, and education to compute total value of student time.

The income-based measure of investment in formal education in Table 6 is substantially larger than the cost-based measure, suggesting a substantial average surplus from education. Abraham (2010) discusses the frequently-noted differences between income- and cost-based measures of investment in education in detail. She notes that "[i]n contrast to the market accounts, where money spent on purchases for final demand must flow into someone's pocket as income, there is no conceptual identity between returns and costs for investment in education." Abraham suggests that one appealing way to include this difference in accounts is as profit to the household sector, although she also notes that the size of the difference may suggest measurement problems, such as possible overstatement of the returns to formal education in income-based measures.

Human Capital Investment and the Great Recession

According to the investment series presented in Chart 3, real market human capital investment in education peaks in 2010, which was also a peak year for the unemployment rate in the Great Recession. The increase in investment in education is driven by an increase in enrollment in higher education, which is historically countercyclical (Dellas and Sakellaris, 2003; Christian, 2007).

Given that alternative approaches to measuring investment in education tend to yield larger estimates than those in the NIPAs, it is possible that measures of overall output that use these alternative approaches will be less cyclical. Chart 7 shows year-to-year changes in GDP using two alternative approaches.

The first alternative approach simply adds the value of time spent in school or study to GDP. This is an implication of the cost approach to measuring investment in human capital, which otherwise typically re-classifies educational expenditure from consumption to investment within GDP. The value of time is measured as in Table 6 above. It is measured in real terms as a chained Fisher volume index of full-time equivalent enrollments, using the opportunity cost of enrollment as a weight, then reflated to constant (2009) dollars. This is added to real GDP. The impact on year-to-year change of adding the value of student time on GDP is small. The total two-year drop in GDP from 2007 to 2009, which is -3.1 per cent in official real GDP, is mitigated only to -2.8 per cent when student time is included. This result is not surprising, since the value of time spent in school or study is less than 3 per cent the size of GDP through the 2010s.

The second alternative approach considered uses the income approach to measuring investment in education. This approach subtracts the component of official GDP that is attributable to education and adds in the market component of investment in education net of aging measured as described above. This is also a Fisher index of enrollments, but in this case weighted by lifetime incomes, and is the same as the series presented in Table 1 and in Chart 3, except reflated to 2009 rather than to 2013 dollars. The subtracted-out component of official GDP attributable to education is real personal consumption expenditures for education, plus an estimate of real government consumption expenditures for education.[6]

Using the income approach to measure investment in education has a more substantial effect on year-to-year changes in GDP. This should be less surprising, given that it changes GDP substantially, as well; the proportion of GDP that is attributable to education becomes much larger, increasing from 6 per cent of GDP to 23 per cent of GDP in 2009. It also has the effect of mitigating the Great Recession, reducing the total two-year drop in GDP between 2007 and 2009 from -3.1 per cent to -1.3 per cent.

Conclusions and Possibilities for Continued Research

This article has presented estimates of the stock of human capital using expected lifetime earnings between 1975 and 2013 in the United States. According to the income-based approach of Jorgenson and Fraumeni, the market component of the stock of human capital increased at an average rate of 1.0 per cent per year between 1977 and 2013. The dominant force in the increase in human capital over this time period has been population growth. Growth in the human capital stock per capita did not change substantively over the time period, due to the effects of greater levels of education and an aging population mostly offsetting each other. Measures of investment in education that use the income method are, historically, about three times greater than measures that use a method based on cost.

A natural extension of this work is to estimate a series of updated cost-based estimates of human capital stock and investment. This would provide another perspective on the recent history of human capital in the United States. Extending both a cost-based and income-based series further backward to before 1975 using historical data will yield a longer-term picture of the evolution of human capital in the United States.

The difference between measures of human capital investment and human capital stock between the cost and income approach, such as those presented for investment in education in Table 6, is an important area of investigation for further research into human capital. Abraham (2010) notes a wide range of possible reasons for measured differences in cost- and income-based measures of investment in education, with particular focus on potential distortions in the market for education and on assumptions of the

6 Real personal consumption expenditure on education is estimated from NIPAs Tables 2.4.3 and 2.4.5. Real government consumption expenditure on education is estimated from NIPAs Tables 3.15.3, 3.15.5, and 3.17.

income-based model about productivity and expected lifetime earnings streams.

Another extension of this work is to use the data set to produce results that are closely consistent with international efforts in human capital measurement. The results in this study use methods that were chosen to best fit data sets used in the United States, in particular the Current Population Survey. A good test of the robustness of human capital estimates would be to use the same data to estimate human capital using an approach that most closely matches those of the OECD human capital project (Liu, 2014).

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