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

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Abstract

This study continues the research initiated in Christian (2010, 2014) on measurement of human capital stocks and investment in the United States. It measures 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), compares investment in education between the cost and income approaches, and describes the necessary steps for producing a cost-based series of human capital in the United States.

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I. Introduction

Accounting for human capital continues to be one of the liveliest topics in national statistics. 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 persistence and sustainability of economic resources over time, as an alternative approach to measuring the output and productivity of the education sector, and as an indicator of overall economic well-being.

This study continues the research of Christian (2010, 2014) and measures a series of human capital from 1975 to 2013 using the income-based approach of Jorgenson and Fraumeni (1989, 1992). 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 percent 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 cancelled out by the effect of an aging population. While net investment in education rose annually by 1.0 percent per year, net investment in human capital as a whole declined at an annual rate of 0.1 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, 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 describes the steps necessary to produce a cost-based series for human capital in the United States alongside the income-based series presented here. It also 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 study concludes with a discussion of possibilities for continued research in human capital.

II. 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 an 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). The cost approach measures investment in human capital by the cost of producing it. Kendrick (1976) includes in investment the costs of rearing children to working age, of education and training, of health and safety (although only in part, attributing the other part to maintenance), and of job search, hiring, migration, and other costs associated with labor 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 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. 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, natural capital, and other tangible capital. Intangible capital includes human capital and social/institutional capital.

III. 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 Cooperation and Development (OECD) (Liu, 2014). This project covers sixteen countries: Australia, Canada, Denmark, France, Israel, Italy, Japan, the Republic of Korea, Netherlands, New Zealand, Norway, Poland, Romania, Spain, the United

Kingdom, and the United States. It measures the stock of human capital over time between 1997 and 2007, 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 measured a version of the human capital stock that included 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.

A focus of the OECD project is on cross-country comparisons in the stock of human capital. To make these cross-country comparisons, human capital is deflated using a price deflator based on purchasing power parities (PPPs) for private consumption. For comparisons across different periods over time within a country, the volume of human capital is measured as a volume index that uses population by age, sex, and education as the quantity and per capita lifetime income by age, sex, and education as the weight. This is a very typical way for measuring real human capital over time (Gu and Wong, 2010; Christian, 2014).

The OECD project sets the income growth rate--the rate at which income is assumed to grow when measuring lifetime income--country-by-country, based on real wage and salary growth by country from 1960 to 2007. The income growth rate set for the United States, 1.30%, is very close to the 1.32% income growth rate used in Jorgenson and Fraumeni (1992). The discount rate--the rate at which current and projected future incomes are combined to produce lifetime income in present discounted value--is set at 4.58%, which was employed by Jorgenson and Fraumeni (1992).

The treatment of education in the OECD project follows the 1997 International Standard Classification of Education (ISCED 97) in a way that uses a detailed transition pattern for education. For example, it distinguishes among secondary education designed to lead to postsecondary education, to technical or vocational education, or directly to the labor market. This is in contrast to the original Jorgenson-Fraumeni papers, which defined levels of education by years of education. This paper, like earlier papers (Christian 2010, 2014), continues to use years of education given how straightforwardly data in the United States lends itself to measuring education by individual year. However, the impact of an alternative treatment of education on measures of human capital is a promising subject for continued research.

Liu (2014) illustrates many clever applications of cross-country estimates of human capital in the OECD project. Given that the countries studied are of different sizes, the focus of cross-country comparisons is on the ratio of the human capital stock to GDP (normally between 9 and 11), on the ratio of the human capital stock to the physical capital stock (around 5 on average), and on human capital per person of working age (in 2006, typically between $400,000 and $550,000, and highest in the United States of all countries at $641,000). Liu (2014) measures Gini coefficients to measure the equality of distribution of human capital across gender, education, and age within individual countries. He also decomposes average annual growth in per capita human capital across changes in the distribution of the population by age, by gender, and by level of education. He finds that per capita human capital has declined in real terms in the United States between 1997 and 2007, primarily a result of the effect of rising levels of education not keeping up with the effect of aging.

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 (Rensmann, 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). Rensmann's (2013) study of the Netherlands makes a clever comparison of the estimated human-capital-to-GDP ratio to the product of labor's share of GDP and a representative worker's ratio of lifetime income to current income given the assumed discount rate, income growth rate, and average age within the working-age population. She finds that the two yield results of a similar magnitude. Gu and Wong (2015) make an adjustment for the quality of education based on literacy scores when measuring real growth in educational investment in Canada. This is a departure--a potentially necessary departure--from the more common approach in lifetime income models of assuming that the quality of education is static over time within levels of education by age and sex. Fraumeni *et al* (2015) integrated human capital estimates based on the lifetime income approach into a broader national economic account, using results both from Jorgenson and Fraumeni (1989) and Christian (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.

The United Nations Economic Commission for Europe (UNECE) has 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. The task force, which is primarily made up of members of national statistical agencies, has the goal of presenting final guidelines to the Council of European Statisticians in June 2016.

IV. 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 thirty-nine year period between 1975 and 2013. The extended series includes both market and non-market 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. A complete series of human capital for 1975 to 2013 is presented in the Appendix and is summarized and discussed in this section.

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 data and working backwards. In the results presented in this paper, the oldest age is 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, and is 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:

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

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 paper, 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 labor 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, of employer contributions to Social Security, etc. 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 labor compensation.

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 set to time not spent at work, in school, or in personal maintenance. Time spent in school is assumed to equal 1300 hours 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 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 alternatively 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 income. In the results in this paper, 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. The above equation is set up so that investment takes place before revaluation, but it can be set up the other way around, as in the original Jorgenson-Fraumeni papers.

Net investment can further be broken down into different components. In this study, 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 approach of the original Jorgenson-Fraumeni papers. 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 of 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 the right assumption, however. An alternative assumption is that people who actually attended school would, had they missed a year for exogenous reasons, just picked 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 getting 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 that is in this study 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. 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.

Net investment in the latest year, 2013, is measured a little differently from earlier years, since data on the distribution of the population by age, sex, and education in the following year, 2014, is not yet known given the absence of available microdata at the time of writing. In this case, the population by age, sex, and education is assumed to be that which would be predicted from births, deaths, education, and aging in 2013, multiplied by the ratio of the total population in 2014 to the total population predicted for 2014 from births and deaths in 2013.

Most components of 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. This is straightforwardly the case with investment from births, depreciation from deaths, and investment from education net of aging of enrolled persons. Depreciation from aging of the non-enrolled is split into two: aging up to age 6, which is typically appreciation, and aging from age 6 onward, which is typically depreciation. (Note that this measure only includes persons who are not enrolled in school, which will be a very small number of children between ages 6 and 14.) These are separately measured as chained Fisher volume indexes, which are then multiplied by nominal depreciation from aging for their respective age ranges in 2013 to convert to constant 2013 dollars. Total real depreciation from aging is then computed by adding the two.[1] 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 out investment from births and education, and adding in 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. The October supplements from 1975 to 2013 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.

Up until 1991, the CPS measured educational attainment using individual years of education, with no education as the lowest measured level of education and eighteen years of

[1] Measures of real net investment are not substantively different when measured using a single index that encompasses all ages rather than splitting it into two parts using separate indexes for young children and for older children and adults.

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 reasonably well measure educational attainment by individual year. From 1992 to 1997, however, it is necessary to impute the distribution by individual years of education of much of the population from the information about credentials earned only.

In the October CPS, no imputation of education was necessary in 1992-1997 for people who were enrolled in school, because enrolled people were asked in all years of the October CPS the year of school in which they were enrolled. In these cases, the reasonable assumption was made that their educational attainment was one year lower; in fact, this assumption was made throughout the entire 1975-2014 period. Among people who were not enrolled in school, the imputation was made by computing the distribution of the population by age, sex, and the interaction of individual years of school and degrees and credentials earned in 1991 and in 1998. For 1991, this was computed using a matched October 1991-October 1992 sample, since years of education are only available in the former and credentials are only available in the latter. For 1998, this was computed using only the October 1998 sample, since it contained both education measures. The number of people by age, sex, and educational credentials as measured by the October CPS between 1992 and 1997 were then distributed across individual years of education using a linear interpolation of the proportion of people by age, sex, and educational credentials across individual years of education in 1991 and 1998.

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.

The March CPS is used to measure averages rather than aggregates: in particular, average number of hours worked and average pre- and post-tax hourly earnings. These were imputed by individual year of education in 1992-1997 as average hours worked and average hourly earnings among people with a degree or credential typically associated with that year of education, multiplied by a factor that reflects a typical ratio of hours or wages between the year of education and the degree or credential earned. For example, average earnings for people with sixteen years of education might be imputed as average earnings for people with bachelor's degrees, multiplied by 0.9 to reflect the likelihood that not everyone with sixteen years of education has completed a bachelor's degree. The factors were computed empirically by age, sex, and credential for 1992 using a matched December 1991-March 1992 sample and for 1998 using only the March 1998 sample, and then linearly interpolated over 1993-1997.

Weighting of observations in the Current Population Survey changed multiple times over the period studied to reflect information from recent decennial Censuses, with changes in weighting taking place in 1982, 1994, 2003, and 2012 to reflect the censuses in 1980, 1990, 2000, and 2010. To avoid disruption, shifts in average weights by age, sex, and educational attainment at the time of the change were spread out over the course of the period between changes in weights for the changes in 1994, 2003, and 2014. In 1994 and 2012, this shift was measured using matched October 1993-January 1994 and October 2013-January 2014 samples. In 2003, weights based on both the 1990 and 2000 Census were available in the data set, and so the shift was measured using only the October 2003 data set. No backward adjustment to 1975 was made for the change in weights in 1982, which did not appear to have a disruptive effect on the empirical results.

Federal and state marginal 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 only computes state marginal tax rates 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.

Average hours, pre-tax hourly earnings, and post-tax hourly earnings were imputed for combinations of age, sex, and education that only appeared in small numbers (fewer than 20 observations) in the March CPS sample using a regression of the outcome variable on interactions among year, age, sex, and a linear spline function of years of education with knots at twelve and sixteen years.

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. School enrollments are adjusted to match elementary, secondary, and college enrollment numbers reported in the *Digest of Education Statistics*. The adjustment, which is made using a simple multiplicative factor, is intended to mitigate any idiosyncrasies in the October CPS.

Death rates by age and sex are measured using life tables of 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 income growth rate is assumed to be 2 percent, and the discount rate is assumed to be 4 percent.

Income-based human capital measures, 1975-2013

Table 1 below 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 focused on in recent applications.

Table 1. Market human capital, 1977-2013 (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	$1.7	-0.1%
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	$0.8	

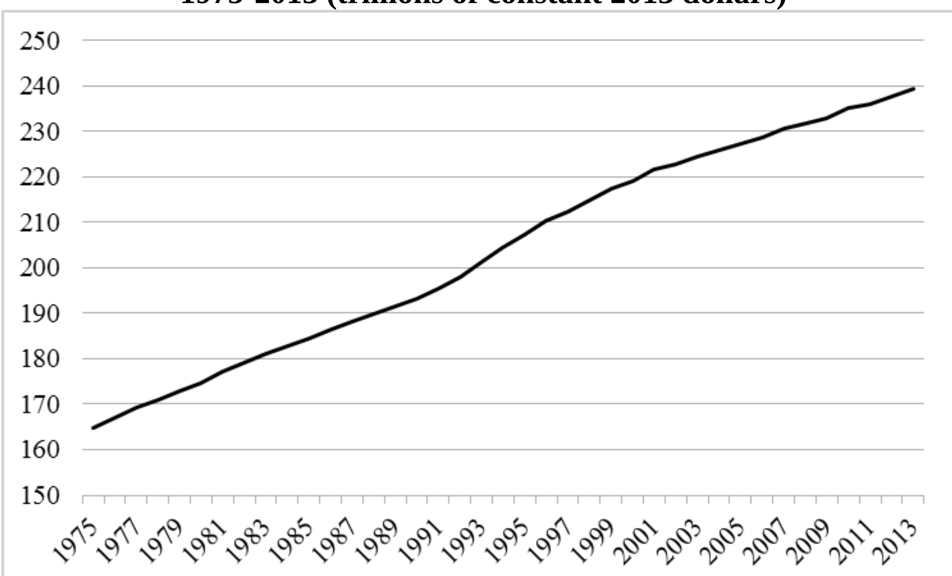
The market component of the human capital stock is about one-third of the combined market and non-market human capital stock. The proportion of the total human capital stock that is in the market component has declined steadily over the time period covered, from a peak of 33 percent in 1977 to a low of 29 percent in 2013.[2] As can be seen in Table 1, the market component of the human capital stock has increased at an annual rate of 1.0 percent per year between 1977 and 2013. This is the same as the rate of population growth over the same period of time,

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

suggesting that virtually all increase in the total human capital stock in the past thirty-six years can be attributed to the population becoming larger. The full series of human capital estimates, including both market and nonmarket components, is presented in the Appendix.

Figure 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 1990's and a slowdown in the twenty-first century.

Figure 1. Market component of stock of human capital, 1975-2013 (trillions of constant 2013 dollars)



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

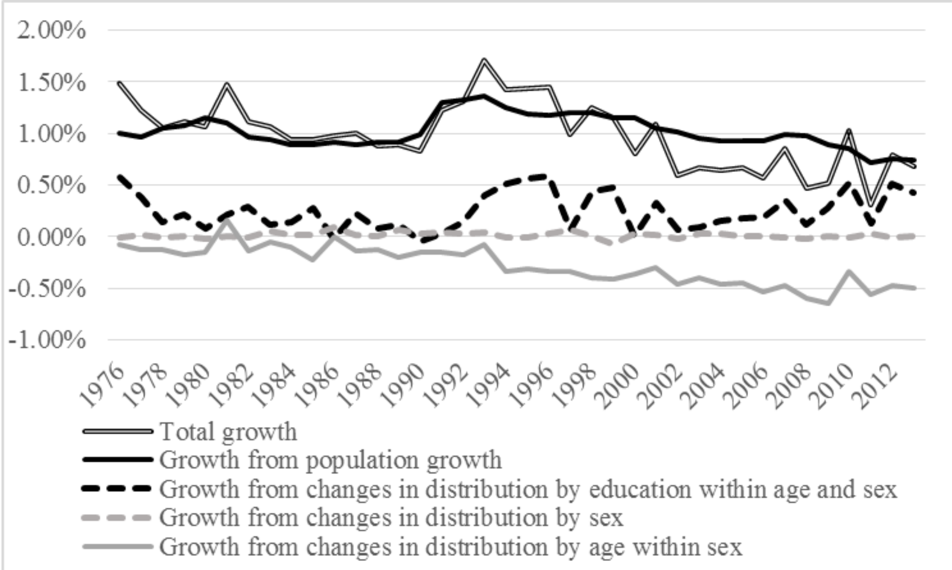
Growth from changes in the distribution of population by age within sex
$= \Sigma_s\Sigma_a\Sigma_e [(pcount_{y+1,s(y+1),a(y+1),e(y)} - pcount_{y+1,s(y+1),a(y),e(y)}) \times i_{y+1,s,a,e}] / \Sigma_s\Sigma_a\Sigma_e (pcount_{y,s,a,e} \times i_{y+1,s,a,e})$

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, 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 is consistently around 50-50 over time, and so its placement is not especially relevant. Since education is substantially determined by age among younger people, it makes sense to decompose by age before education.

Figure 2 presents a graphical decomposition of yearly changes in human capital by population, age, sex, and education over the 1975-2013 period.

Figure 2. Year-to-year changes in the market component of the real human capital stock, 1975-2013



A more detailed accounting of changes in the stock of human capital between 1977 and 2013 is presented in Table 2. This 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 wide period of time, results are presented using both 1977 and 2013 lifetime incomes as fixed weights.

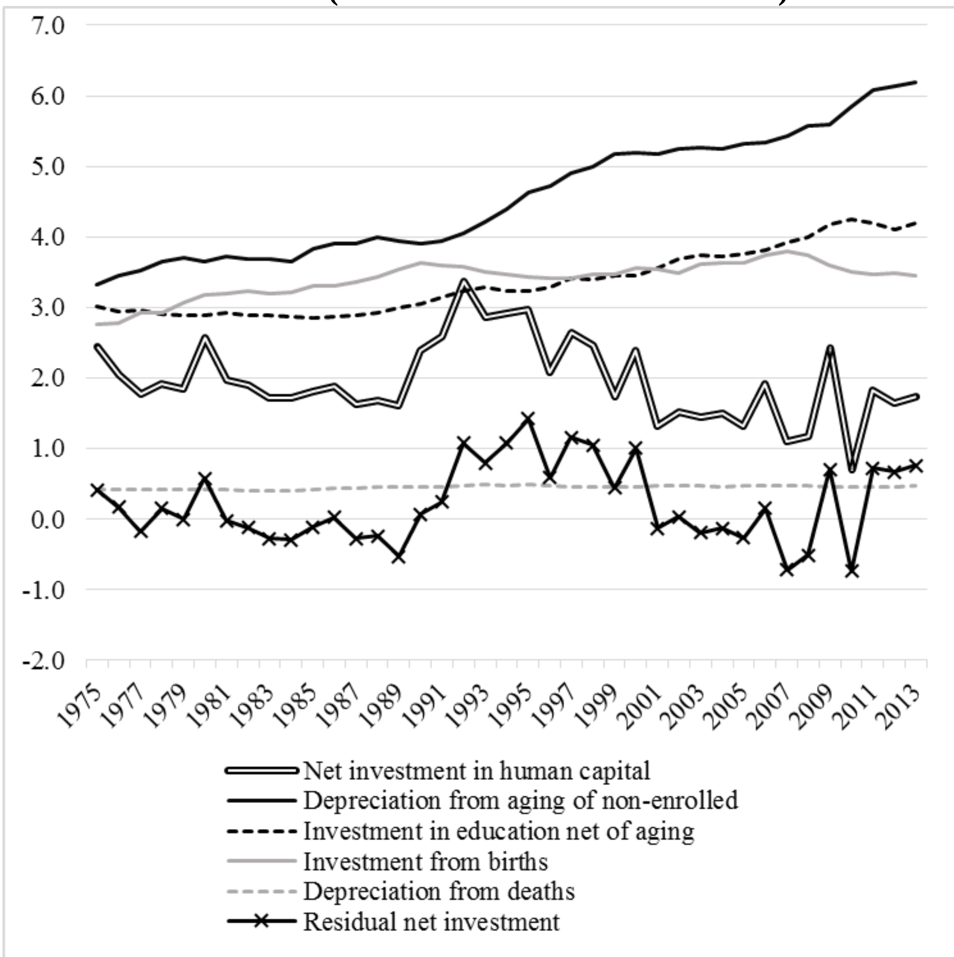
Table 2. Decomposition of total growth in the real market human capital stock, 1977-2013

	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%

Between 1977 and 2013, the dominant driver of change in the stock of human capital was population growth. Outside of population growth, the most important drivers of change in human capital are an increase in the 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, and 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 impacts of education and aging have for the most part mitigated each other over this time period.

Figure 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 1990's. 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. A complete set of nominal and real measures of investment in and depreciation of human capital can be found in the Appendix.

Figure 3. Investment in market component of human capital, 1975-2013 (trillions of constant 2013 dollars)



Wages, salaries, self-employment income, and compensation

One possible shortcoming of the results presented here is that lifetime labor income is measured using only wages, salaries, and self-employment income. Human capital is a measure of the long-run productive capacity of a population. The most appropriate way to value human capital is with the value of lifetime production, which will be more accurately reflected in the employer cost of labor, or the value of labor to the persons and firms who employ labor to produce goods and services. As a result, when using lifetime earnings to measure human capital, the measure of earnings used should include all costs to the employer of employing persons. This includes non-money benefits such as health insurance, deferred payments such as contributions to pensions, and taxes such as employer contributions to Medicare and Social Security.

It is difficult to measure these costs on the Current Population Survey, which is a household survey rather than an employer survey. However, the impact of excluding these can be approximated using a simple multiplier, equal to the ratio of wage, salary, and self-employment compensation to total compensation. This approximation assumes that this ratio is roughly equal by age, sex, and education. When this ratio is measured using the NIPAs, it increases steadily from 1.15 in 1975 to 1.21 in 1992, and remains around 1.2 since.[3] Multiplying all aggregates by this multiplier is a relatively simple way to adjust results for not having included compensation outside of wages, salaries, and self-employment income.

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 papers, 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 earnings, 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 the multiplier described in the previous section to reflect total compensation rather than just wages, salaries, and self-employment income;
- The income growth rate is set to 1.32% and discounting is set to 4.58% for comparisons with results in Jorgenson and Fraumeni (1992).

The results of the comparison are presented in Table 3 below.

[3] This is computed using Table 2.1 of the NIPAs, as the ratio of the sum of compensation (line 2) and proprietor's income (line 9) to the sum of wages and salaries (line 3) and proprietor's income (line 9).

Table 3. Human capital stock and investment in education, market and non-market, billions of current dollars, comparison with Jorgenson-Fraumeni

	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)	Christian (2015)	Jorgenson-Fraumeni (1992)	Christian (2015)	Jorgenson-Fraumeni (1992)	Christian (2015)
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

Note: Results adjusted to match modeling in Jorgenson-Fraumeni as described in body text. In the column labels, IG is the income growth rate, while D is the discount rate.

In addition to the comparison above, Fraumeni *et al* (2015) note that investment in education in Jorgenson-Fraumeni (1989) is $2,383.9 billion in 1982. In this study, I estimate it at $4,551.1 billion ($3,786.6 billion from wages and salaries alone, times the 1.174 adjustment for the compensation multiplier). The human capital stock results from this study roughly match measures of the human capital stock in Jorgenson and Fraumeni (1989), but estimate a substantially higher measure of investment in education. 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.[4]

[4] Fraumeni *et al* (2015) compares results from 1982 in Jorgenson and Fraumeni (1989) to results from 2009 in Christian (2014) and finds substantive differences between the two 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.

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.

Table 4. Active and nascent market human capital, 1977-2013 (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	2.0	-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	0.6	0.2
Transfer, nascent to active stock, age 15	1.2	-1.2	5.1	-5.1
Net investment (excluding transfer)	-0.5	1.0	-3.2	4.9

The proportion of the human capital stock that is active has increased over time, from 70 percent in 1977 to 73 percent 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 labor force participation by older people. A complete series of active and nascent human capital is presented in the Appendix.

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 percent to 67 percent active and 33 percent to 40 percent 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.

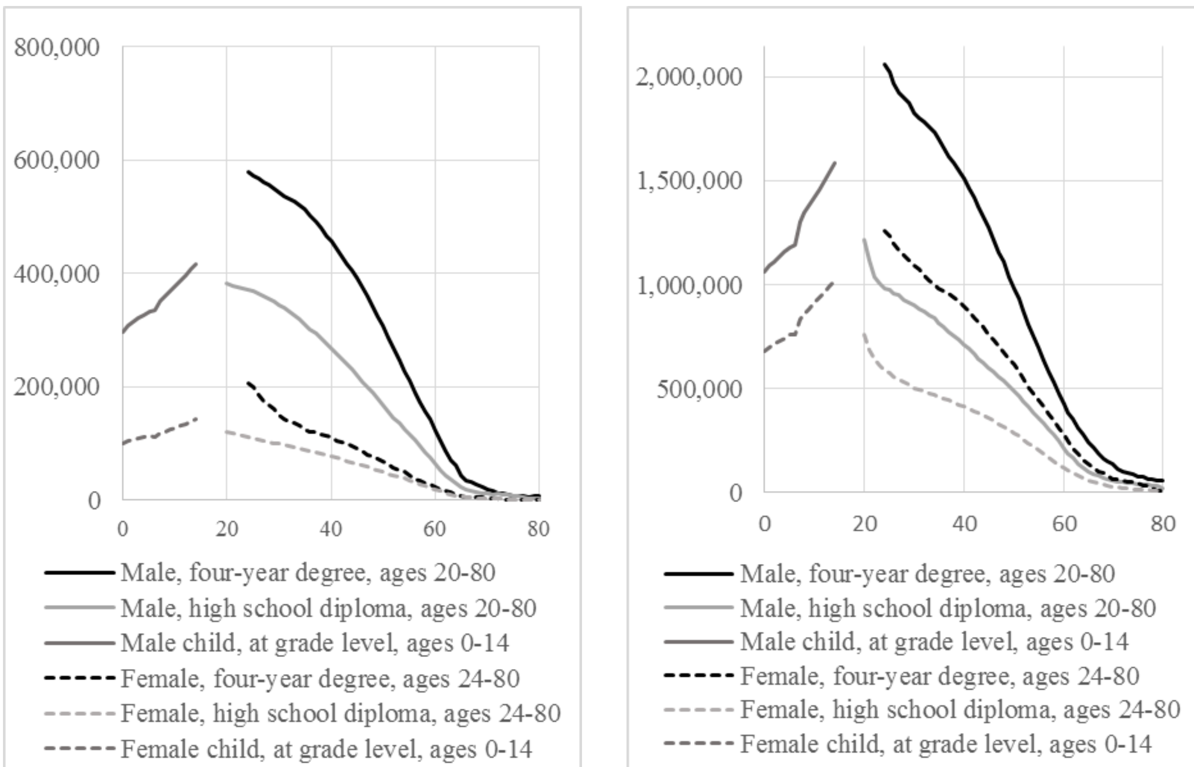
Even if one regards the active human capital stock as the important stock measure, it is nonetheless useful to account for net investment in both the active and nascent stocks. This is because net investment in the nascent stock ultimately accumulates to the active stock as cohorts within the nascent 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. Investments in the nascent stock are accounted for at the time that the investment is made: at the time children are born, for example, or at the time children receive elementary education. When children reach age 15 and enter the active human capital stock, an approach that accounts for both the active and nascent stock will recognize that there is no new investment at that time, but instead only a transfer of human capital from the nascent stock to the active stock.

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. Figure 4 illustrates lifetime earnings, measured using cross-sections from 1977 and 2013, for men and women at different ages and different levels of education.

Figure 4. Lifetime earnings by sex, age, and education (current dollars)

1977 **2013**



The two graphs in Figure 4 are aligned so that lifetime earnings at age 40 for a man with a high school diploma line up horizontally. In both graphs, 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 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 older than 65, lifetime earnings are computed for this particular application under the assumption that earnings are zero at age 65 and older.

Figure 5 below 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. Figure 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.

Figure 5. Per capita active market human capital (1975 = 100)

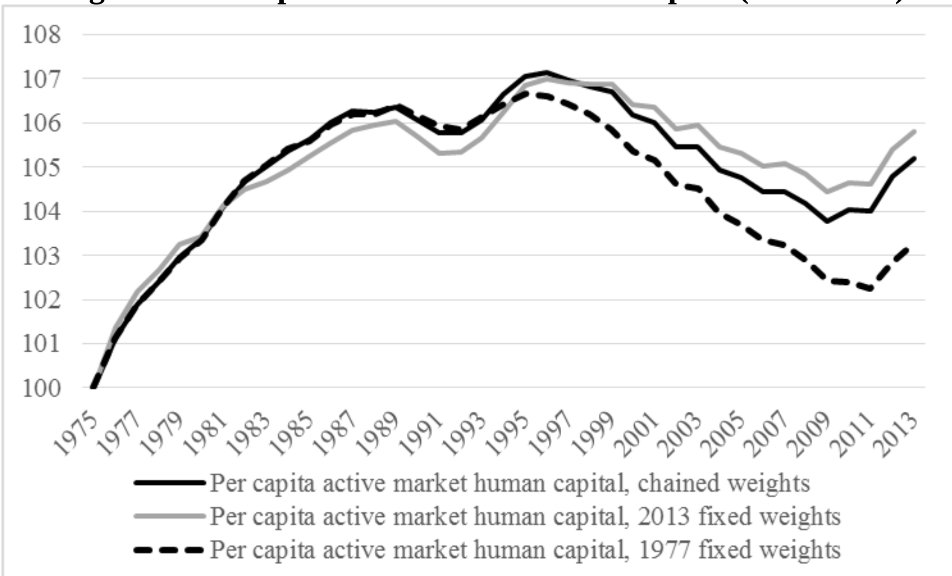
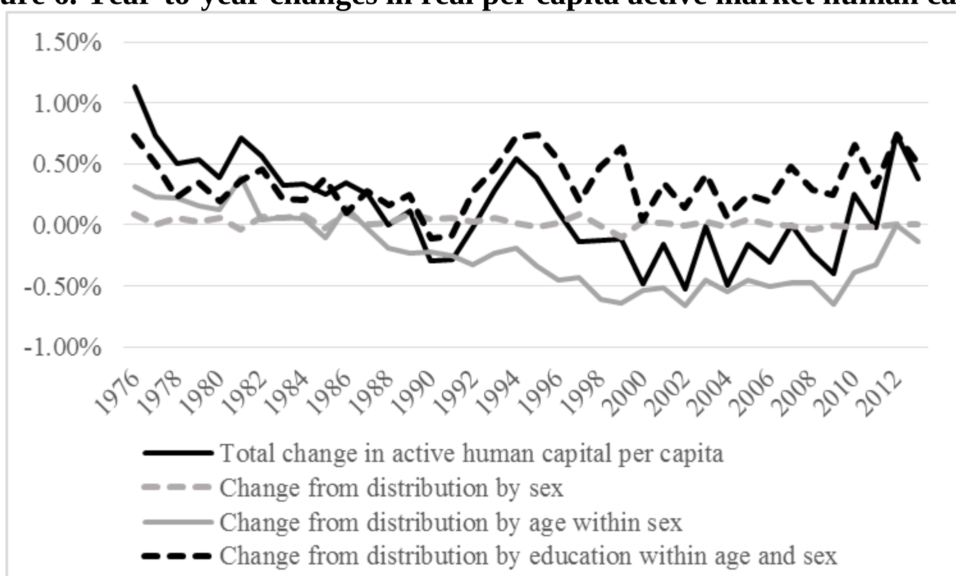


Figure 6. Year-to-year changes in real per capita active market human capital



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. For the most part, per capita human capital rises quickly in the late 1970's and 1980's, levels out in the 1990's, declines in the 2000's, and rises again in the early 2010's. Note that changes in per capita human capital over the 1975-2013 period differ depending on whether lifetime incomes from the late 1970's or the early

2010's are used to value it. This is likely because the return to education is considerably higher in the 2010's than in the 1970's, 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 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.

Table 5. Ratio of market human capital to GDP and fixed assets, 1977 and 2013

	Human capital to GDP	Active human capital to GDP	Human capital to fixed assets	Active human capital to fixed assets
1979	19.71	13.72	7.17	4.99
2013	14.28	10.48	4.91	3.61

Note: Fixed assets are lagged one year because the NIPAs use year-end estimates.

V. 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, of education and training, of health and safety, and of labor mobility. Rearing children to working age is considered a tangible component of human investment, while education and training, health and safety, and labor mobility are considered intangible components.

In Kendrick's account, investment in rearing children to working age includes personal consumption expenditures related to raising children, but does not include the opportunity cost of parents' time. Education and training investment includes expenditures on formal, informal, religious, and military education, as well as the costs of employee training. Investment in formal education includes not only private and government consumption expenditures for education and research and rental costs for educational structures and equipment, but also the opportunity cost of students' time. Investment in informal education covers a wide variety of goods and services related to education, including libraries, recreation, museums, radio, television, records, books, periodicals, and advertising, although many of these only enter the cost of informal education in part using a proportion attributable to education.

Medical, health, and safety investment includes half of expenditures for medical, health, and safety purposes. The other half is considered maintenance that does not have an impact on productivity. It includes personal, business, and government consumption expenditures related to health and safety, as well as rental costs of hospital and other medical structures and equipment. Labor mobility costs include costs of job search by both the personal and business sectors as well as work-oriented migration costs.

To measure the gross stock of human capital in a given year for rearing children, education and training, and health and safety, Kendrick took population by age, multiplied it by per capita human investment in these areas accumulated from birth to the current year by age, and then summed the resulting product across ages. To measure the net human capital stock in these areas, lagged investments were depreciated with the aging of the persons in which the investment is made. Investment in child-rearing and in health and safety are depreciated from age eighteen through age seventy-five, and investment in education and training are depreciated from age twenty-five through age seventy-five, using double-declining balance switched to straight-line depreciation. The methods chosen for depreciating child-rearing, health and safety, and education and training were intended to reflect how their impact on lifetime income diminishes with time. The lifetime income measures used by Kendrick to motivate his choice of depreciation method are from Miller and Hornseth (1967), who used a similar approach to measuring lifetime income as Jorgenson and Fraumeni.

Investments in job mobility were assumed to have lives equal to the reciprocal of the fraction of people who benefit from a job mobility cost. For example, a mobility investment associated with twenty percent of employed people is assumed to have a life of five years.

One especially useful aspect of the cost approach to measuring the stock of human capital is that it not only makes it possible to measure an aggregated stock of human capital, but also disaggregated stocks based on individual components of human capital. One can produce a measure of the specific stock built from investments in child-rearing, for example, or from investments in formal elementary and secondary education.

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 just market earnings but also household production. However, inclusion of the nonmarket 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 experienced while 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 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, line 100) and government consumption expenditures for education (NIPAs Table 3.17, line 9) 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 will require 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 below provides a comparison of human capital investment from formal education using these two approaches.

Table 6. Income- and cost-based measures of investment in formal education, 1977 and 2013 (billions of current dollars)

	Cost-based education investment				Income-based education investment	Ratio of income and cost measures
Year	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	267.8	739.9	412.6	1,420.3	4,193.8	2.95

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 the Internet version of TAXSIM. This is the same post-tax wage rate used in the computation of non-market human capital earlier in this paper. 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 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.

In contrast, the approaches to human capital investment in bringing children into adulthood are quite different between Kendrick's cost model and Jorgenson and Fraumeni's income model. In the cost model, consumption by children from birth to age 14 is considered investment in human capital as the cost of bringing children to an age at which they are old enough to engage in productive work. In the income model, on the other hand, children are born with a human capital endowment equal to lifetime income from birth in expected present discounted value. As a result, births are associated with a substantial investment in human capital in the income model, but not in the cost model.

Some of this difference may be bridged by limiting focus to active human capital, i.e. human capital embodied in persons of working age. In the income approach, one can measure investment in active human capital as the arrival of children into working age. This is the approach of Table 4, which presents a measure of $5.1 trillion being transferred from the nascent (children) human capital stock to the active (adult) human capital stock in 2013 as children age from fourteen to fifteen. Note that this investment embodies all investments made up in children through childhood, including education. A similar approach could be used in the cost method. This approach would take accumulated rearing costs, education costs, and other relevant costs of bringing children to adulthood for a given cohort and account for them as investment in the active human capital stock at the time that the child entered adulthood. This is similar to the approach of Kokkinen (2011), which considered human capital investments made as a child as having accumulated into an inventory that entered the human capital stock when the child became an adult.

Medical costs, which is included in human capital investment in Kendrick, does not have an evident analogue in gross investment in human capital in Jorgenson and Fraumeni. However, given that deaths are an aspect of depreciation in Jorgenson and Fraumeni, medical costs will be reflected in net investment in human capital to the extent to which they sustain lives. Job search costs, another aspect of human capital investment in Kendrick, does not have an obvious analogue in Jorgenson and Fraumeni.

Immigration, which is a source of investment in human capital in Jorgenson and Fraumeni, is accounted for in Kendrick as a transfer of human capital from the rest of the world. Deaths and emigration are accounted for in Jorgenson and Fraumeni as depreciation and in Kendrick as retirement of human capital. Aging of persons of working age is accounted for in both accounts as depreciation. In this context, the distinctions between investment and transfer or between retirement and depreciation are probably similar enough as to be a distinction without a difference.

Measuring the human capital stock using the cost method

Measuring the human capital stock is a more challenging endeavor than measuring human capital investment when using the cost method. The income method measures the human capital stock based on predictions about earnings in the future. The cost method, by contrast, measures the human capital stock based on information about investments in the past. For this reason, the two approaches can be described respectively as "prospective" and "retrospective" approaches (Kokkinen, 2011).

In the cost method, measuring the human capital stock in the present involves accumulating human capital investment over the entire lifetimes of all persons included in the human capital stock in the present. This requires a time series of human capital investment that extends backward for many years, from the present (or the year in which one wants to measure the human capital stock) all the way back to the earliest point at which people would have received investments in human capital that continue to be embodied in them in the present. For example, suppose one wanted to measure the stock of human capital in 2013, and one also assumed that the oldest people who continue to be productive as a result of past human capital investments are eighty years old. If people begin higher education at age 18, then measuring the stock of human capital from higher education would require a series of investment from higher education that extends backward to 1951, the earliest year at which eighty-year-olds in 2013 would have begun attending higher education. Measuring the stock of human capital from child rearing would require extending this series back to the birth of the oldest people included in the human capital stock measure; in this example, it would require extending it back to 1933. Kendrick, who measured the human capital stock up to age ninety-five and measured the human capital stock as early as 1929, had to measure some aspects of human capital investment all the way back to the 1830's. The time series in past investments must be deflated to constant dollars before it is accumulated into a stock.

The cost method to measuring the human capital stock also requires a scheme for depreciating and retiring past investments. It is important to note that the approach to depreciation and retirement must be chosen in a way that can be supported by the level of detail in the backward-looking series of investments. For example, Kendrick's approach to depreciating many aspects of human capital depended on age; human capital investment from child-rearing did not begin depreciating until age 18, and human capital investment from education did not begin depreciating until age 28. It also included an approach to retiring human capital that depended on age, which used the ratio of population in an age cohort in the present relative to that in the past. As a result, Kendrick's backward-looking series of investment needed to be disaggregated in each year by the age of the person benefitting from the investment in order to be accumulated into a stock.

If the evolution of lifetime income by age is any guide, a straight-line approach to depreciating human capital may be an appropriate one for much of one's working life. From age 25 to age 65, the graph in Figure 4 suggests that the decline in lifetime income is roughly linear. Kendrick notes this, using the lifetime income results of Miller and Hornseth (1967), but recommends and employs a double-declining-balance-switched-to-straight-line depreciation approach, in part because it matches approaches by which other assets are depreciated.

When building up the human capital stock from lagged investment and depreciation, some account must be made for immigration and emigration. Persons who have immigrated to the

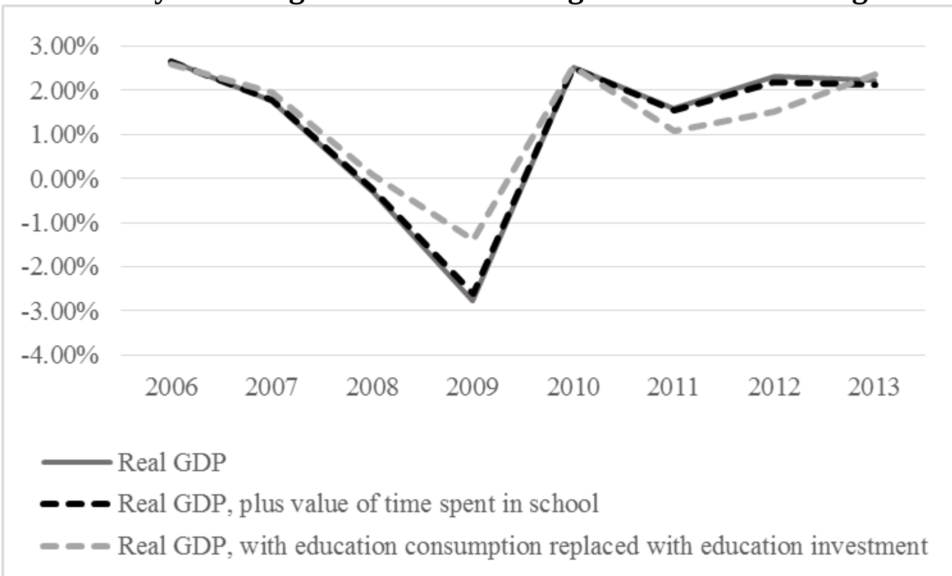
United States are not covered in all lagged investments in the human capital stock in the United States in their lifetimes, and so the human capital stock in the United States will include some human capital investments made outside of the United States. Similarly, emigrants from the United States take some past investments in human capital made within the United States and take them out of the American human capital stock into the stocks of their destination countries.

VI. Human Capital Investment and the Great Recession

According to the investment series presented in Figure 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), likely driven by the opportunity cost of education being lower when job prospects are worse. Long (2015) identifies several different factors relevant to the supply and demand of higher education in the Great Recession, including higher unemployment, an increase in financial aid, lower family incomes and home equity, more constrained credit markets, higher tuition prices, a large graduating high school cohort, and strained institutional capacity.

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. Figure 7 yields year-to-year changes in gross domestic product using two alternative approaches.

Figure 7. Year-to-year changes in real GDP using different accounting for education



The first alternative approach considered simply adds the value of time spent in school or study to gross domestic product. 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% in official real GDP, is mitigated only to -2.8% when student time is included. This result is not surprising, since the value of time spent in school or study is less than 3 percent the size of GDP through the 2010's.

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 Figure 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.[5]

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 percent of GDP to 23 percent 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% to -1.3%.

VII. Conclusions and Possibilities for Continued Research

The results above measure the stock of human capital using expected lifetime earnings between 1975 and 2013. According to the income-based approach of Jorgenson and Fraumeni, the stock of human capital increased at an average rate of 1 percent 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 cancelling each other out. 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.

[5] Real personal consumption expenditure (PCE) on education is computed by multiplying the quantity index for education PCE in line 100 of NIPAs Table 2.4.3 by nominal PCE for education in 2009 in line 100 of NIPAs Table 2.4.5. Real government consumption expenditure (GCE) on education is computed in three steps. First, real government consumption and gross investment (G) on education is computed by multiplying the quantity index for G for education in line 12 of NIPAs Table 3.15.3 by nominal G for education in 2009 in line 29 of NIPAs Table 3.15.5. Second, the consumption share of government consumption and gross investment on education is computed by dividing nominal education GCE in line 9 of NIPAs Table 3.17 by nominal G on education, which is the sum of lines 9 and 108 of NIPAs Table 3.17. Real GCE for education is estimated by multiplying real government consumption and gross investment for education by the consumption share of government consumption and gross investment for education.

A natural extension of this work is to use the discussion of the cost method of measuring human capital as a starting point to estimate a series of updated cost-based estimates of human capital stock and investment. This would provide another look at the recent history of human capital in the United States. Ideally, cost- and income-based measures of human capital would complement each other, and use similar notions of investment and stock. Extending both the 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 investment and 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, one that can only be helped by having a long, recent series of each. 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 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), or which meet as closely as possible the eventual recommendations of the United Nations task force on human capital. One area that might be especially useful for checking robustness is the specification of education, which is measured in individual years in this study but which is measured using the ISCED 97 classifications in the OECD project.

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Appendix

Table A1. Combined market and non-market human capital, 1975-2013
In current dollars (trillions)

		Net human capital investment						
Year	Stock	Total	Births	Deaths	Education	Aging	Residual	Revaluation
1975	109.7	1.4	1.6	0.5	1.0	1.2	0.5	6.7
1976	117.8	1.3	1.7	0.5	1.1	1.4	0.4	5.3
1977	124.3	1.3	1.8	0.5	1.1	1.5	0.3	8.2
1978	133.9	1.5	2.0	0.6	1.2	1.6	0.5	14.4
1979	149.8	1.6	2.3	0.6	1.3	1.8	0.5	11.4
1980	162.8	2.1	2.5	0.7	1.4	1.9	0.7	10.9
1981	175.8	1.8	2.7	0.7	1.5	2.1	0.4	14.9
1982	192.5	1.9	3.0	0.8	1.5	2.1	0.4	14.1
1983	208.5	2.0	3.2	0.8	1.7	2.3	0.2	8.5
1984	219.0	2.1	3.4	0.9	1.8	2.5	0.3	9.6
1985	230.7	2.3	3.6	0.9	1.9	2.7	0.5	11.1
1986	244.0	2.4	3.8	1.0	2.2	3.0	0.5	18.6
1987	265.0	2.4	4.1	1.1	2.2	3.1	0.3	10.8
1988	278.2	2.6	4.4	1.1	2.5	3.6	0.3	21.7
1989	302.5	2.7	5.0	1.2	2.7	3.7	0.0	13.1
1990	318.3	4.1	5.4	1.3	2.8	3.8	1.0	12.4
1991	334.8	4.6	5.6	1.4	3.1	4.0	1.3	14.0
1992	353.5	5.6	5.7	1.5	3.3	4.2	2.2	5.2
1993	364.3	4.9	5.7	1.5	3.5	4.6	1.8	5.7
1994	374.9	5.1	5.6	1.6	3.6	4.8	2.3	11.9
1995	391.9	5.2	5.6	1.7	3.8	5.1	2.5	20.7
1996	417.7	4.7	5.9	1.8	4.0	5.3	2.0	12.0
1997	434.5	5.4	6.1	1.8	4.3	6.0	2.7	21.4
1998	461.3	5.8	6.5	1.8	4.4	6.2	2.9	21.9
1999	489.0	4.9	6.8	2.1	4.9	6.7	1.9	8.3
2000	502.2	5.9	7.3	1.9	4.9	7.2	2.9	29.4
2001	537.5	4.3	7.7	2.1	5.1	7.5	1.1	19.5
2002	561.3	4.9	7.9	2.2	5.4	7.8	1.6	22.9
2003	589.1	4.6	8.5	2.2	5.9	8.5	0.9	22.8
2004	616.5	5.1	8.8	2.4	5.9	8.3	1.0	21.7
2005	643.3	5.1	9.2	2.6	6.2	8.7	0.9	24.5
2006	672.9	6.8	9.9	2.5	6.4	9.1	2.1	29.9
2007	709.6	5.1	10.5	2.8	6.6	9.2	0.1	8.1
2008	722.8	5.0	10.4	2.7	7.2	10.2	0.4	20.2
2009	748.0	7.1	10.5	2.8	7.5	10.4	2.4	11.4
2010	766.5	4.2	10.0	3.0	7.9	10.7	-0.1	0.5
2011	771.2	6.1	9.7	2.9	8.3	11.6	2.6	19.0
2012	796.3	5.7	9.9	3.2	8.0	11.3	2.3	20.8
2013	822.7	6.2	10.2	3.4	8.5	11.8	2.6	

Table A2. Combined market and non-market human capital, 1975-2013
In constant 2013 dollars (trillions)

		Net human capital investment					
Year	Stock	Total	Births	Deaths	Education	Aging	Residual
1975	557.6	7.2	8.2	2.5	6.3	6.4	1.7
1976	564.8	6.1	8.2	2.5	6.1	6.7	1.0
1977	570.9	5.9	8.7	2.5	6.1	6.8	0.5
1978	576.8	6.3	8.7	2.6	6.0	7.1	1.2
1979	583.1	6.3	9.1	2.5	6.0	7.2	0.9
1980	589.4	7.5	9.4	2.6	6.0	7.1	1.8
1981	596.9	6.1	9.4	2.6	6.0	7.2	0.4
1982	603.0	6.1	9.6	2.6	5.9	7.2	0.4
1983	609.1	5.7	9.5	2.6	6.0	7.2	0.1
1984	614.8	5.8	9.5	2.6	5.9	7.1	0.1
1985	620.7	6.3	9.8	2.7	5.9	7.4	0.7
1986	626.9	6.1	9.8	2.7	5.9	7.5	0.7
1987	633.0	5.7	9.9	2.8	6.0	7.5	0.2
1988	638.8	5.9	10.2	2.8	6.0	7.7	0.1
1989	644.6	5.9	10.5	2.8	6.2	7.6	-0.4
1990	650.5	8.4	10.8	2.8	6.3	7.5	1.7
1991	658.9	9.1	10.7	2.9	6.5	7.6	2.4
1992	668.0	10.6	10.6	2.9	6.7	7.7	3.9
1993	678.6	9.0	10.4	3.0	6.8	8.0	2.9
1994	687.6	9.6	10.3	3.0	6.7	8.3	3.9
1995	697.2	9.3	10.1	3.0	6.7	8.7	4.2
1996	706.5	7.9	10.1	3.0	6.8	8.9	2.9
1997	714.4	9.2	10.1	3.0	7.0	9.3	4.2
1998	723.5	9.0	10.3	3.0	7.0	9.4	4.2
1999	732.6	7.3	10.3	3.0	7.1	9.8	2.7
2000	739.8	8.5	10.5	3.0	7.2	9.8	3.6
2001	748.4	6.0	10.5	3.1	7.3	9.7	1.0
2002	754.4	6.6	10.4	3.1	7.6	9.9	1.6
2003	761.0	6.0	10.7	3.1	7.7	9.9	0.7
2004	767.0	6.4	10.7	3.1	7.6	9.9	1.0
2005	773.4	6.0	10.8	3.2	7.7	10.0	0.8
2006	779.4	7.9	11.1	3.2	7.8	10.1	2.2
2007	787.3	5.6	11.2	3.2	8.0	10.2	-0.2
2008	792.9	5.6	11.1	3.2	8.1	10.5	0.2
2009	798.5	7.8	10.7	3.2	8.5	10.6	2.4
2010	806.2	4.3	10.4	3.2	8.6	11.1	-0.4
2011	810.6	6.5	10.3	3.3	8.5	11.5	2.5
2012	817.1	5.7	10.3	3.3	8.3	11.7	2.0
2013	822.7	6.2	10.2	3.4	8.5	11.8	2.6

Table A3. Market human capital, 1975-2013
In current dollars (trillions)

Year	Stock	Net human capital investment: Total	Births	Deaths	Education	Aging	Residual	Revaluation
1975	35.0	0.5	0.6	0.1	0.6	0.6	0.1	2.3
1976	37.8	0.5	0.6	0.1	0.6	0.7	0.1	2.9
1977	41.1	0.4	0.7	0.1	0.6	0.8	0.0	3.4
1978	44.9	0.5	0.7	0.1	0.7	0.9	0.1	4.4
1979	49.8	0.5	0.8	0.1	0.7	1.0	0.1	3.7
1980	54.0	0.8	0.9	0.1	0.8	1.0	0.3	4.0
1981	58.9	0.6	1.0	0.1	0.8	1.1	0.1	2.8
1982	62.4	0.7	1.1	0.1	0.9	1.2	0.0	3.5
1983	66.5	0.6	1.1	0.1	1.0	1.3	0.0	4.6
1984	71.8	0.7	1.3	0.2	1.0	1.4	0.0	3.5
1985	76.0	0.7	1.3	0.2	1.1	1.5	0.0	4.8
1986	81.5	0.8	1.4	0.2	1.2	1.7	0.1	3.7
1987	86.1	0.7	1.5	0.2	1.2	1.7	0.0	4.1
1988	90.8	0.8	1.6	0.2	1.3	1.9	0.0	7.7
1989	99.4	0.8	1.9	0.2	1.4	2.0	-0.2	2.3
1990	102.6	1.3	2.0	0.2	1.4	2.1	0.1	1.6
1991	105.5	1.4	2.0	0.2	1.6	2.2	0.2	2.5
1992	109.4	1.8	2.1	0.2	1.7	2.3	0.6	2.0
1993	113.2	1.6	2.0	0.3	1.8	2.5	0.5	3.1
1994	117.9	1.7	2.0	0.3	1.9	2.7	0.7	2.3
1995	121.9	1.7	2.0	0.3	1.9	2.8	0.9	6.2
1996	129.8	1.3	2.1	0.3	2.0	3.0	0.5	8.7
1997	139.7	1.7	2.3	0.3	2.3	3.4	0.9	5.4
1998	146.8	1.7	2.4	0.3	2.3	3.5	0.8	8.5
1999	157.0	1.2	2.5	0.3	2.6	3.9	0.4	5.5
2000	163.7	1.8	2.7	0.3	2.5	4.0	0.9	6.6
2001	172.1	1.0	2.8	0.3	2.6	4.1	0.0	6.3
2002	179.4	1.2	2.9	0.4	2.8	4.3	0.2	5.4
2003	186.0	1.2	3.1	0.4	3.0	4.5	0.0	3.3
2004	190.5	1.3	3.2	0.4	3.0	4.5	0.0	7.8
2005	199.6	1.2	3.3	0.4	3.1	4.7	-0.1	9.7
2006	210.4	1.7	3.6	0.4	3.2	5.0	0.3	6.9
2007	219.0	1.0	3.8	0.4	3.3	5.1	-0.5	3.3
2008	223.4	1.1	3.8	0.4	3.7	5.5	-0.4	-1.1
2009	223.4	2.4	3.7	0.4	3.9	5.6	0.7	0.0
2010	225.7	0.7	3.4	0.4	4.1	5.8	-0.7	3.4
2011	229.8	1.8	3.3	0.4	4.3	6.1	0.7	0.1
2012	231.7	1.6	3.3	0.4	4.1	6.0	0.7	6.1
2013	239.4	1.7	3.5	0.5	4.2	6.2	0.8	

Table A4. Market human capital, 1975-2013
In constant 2013 dollars (trillions)

		Net human capital investment					
Year	Stock	Total	Births	Deaths	Education	Aging	Residual
1975	164.7	2.4	2.8	0.4	3.0	3.3	0.4
1976	167.1	2.0	2.8	0.4	2.9	3.5	0.2
1977	169.2	1.8	2.9	0.4	3.0	3.5	-0.2
1978	170.9	1.9	2.9	0.4	2.9	3.6	0.1
1979	172.9	1.8	3.1	0.4	2.9	3.7	0.0
1980	174.7	2.6	3.2	0.4	2.9	3.6	0.6
1981	177.3	2.0	3.2	0.4	2.9	3.7	0.0
1982	179.2	1.9	3.2	0.4	2.9	3.7	-0.1
1983	181.1	1.7	3.2	0.4	2.9	3.7	-0.3
1984	182.8	1.7	3.2	0.4	2.9	3.7	-0.3
1985	184.6	1.8	3.3	0.4	2.8	3.8	-0.1
1986	186.4	1.9	3.3	0.4	2.9	3.9	0.0
1987	188.2	1.6	3.4	0.4	2.9	3.9	-0.3
1988	189.9	1.7	3.4	0.5	2.9	4.0	-0.2
1989	191.5	1.6	3.5	0.5	3.0	3.9	-0.5
1990	193.2	2.4	3.6	0.5	3.1	3.9	0.1
1991	195.5	2.6	3.6	0.5	3.2	3.9	0.2
1992	198.1	3.4	3.6	0.5	3.2	4.0	1.1
1993	201.5	2.9	3.5	0.5	3.3	4.2	0.8
1994	204.4	2.9	3.5	0.5	3.2	4.4	1.1
1995	207.3	3.0	3.4	0.5	3.2	4.6	1.4
1996	210.2	2.1	3.4	0.5	3.3	4.7	0.6
1997	212.3	2.6	3.4	0.5	3.4	4.9	1.2
1998	215.0	2.5	3.5	0.5	3.4	5.0	1.0
1999	217.4	1.7	3.5	0.5	3.5	5.2	0.4
2000	219.2	2.4	3.6	0.4	3.5	5.2	1.0
2001	221.5	1.3	3.5	0.5	3.6	5.2	-0.1
2002	222.9	1.5	3.5	0.5	3.7	5.2	0.0
2003	224.4	1.4	3.6	0.5	3.7	5.3	-0.2
2004	225.8	1.5	3.6	0.5	3.7	5.3	-0.1
2005	227.3	1.3	3.6	0.5	3.8	5.3	-0.3
2006	228.6	1.9	3.7	0.5	3.8	5.3	0.1
2007	230.5	1.1	3.8	0.5	3.9	5.4	-0.7
2008	231.6	1.2	3.7	0.5	4.0	5.6	-0.5
2009	232.8	2.4	3.6	0.5	4.2	5.6	0.7
2010	235.2	0.7	3.5	0.5	4.2	5.9	-0.7
2011	235.9	1.8	3.5	0.5	4.2	6.1	0.7
2012	237.8	1.7	3.5	0.5	4.1	6.1	0.7
2013	239.4	1.7	3.5	0.5	4.2	6.2	0.8

Table A5. Non-market human capital, 1975-2013
In current dollars (trillions)

		Net human capital investment						
Year	Stock	Total	Births	Deaths	Education	Aging	Residual	Revaluation
1975	74.7	0.9	1.0	0.4	0.5	0.6	0.4	4.4
1976	80.0	0.8	1.1	0.4	0.5	0.6	0.3	2.4
1977	83.2	0.8	1.2	0.4	0.5	0.7	0.3	4.9
1978	89.0	1.0	1.2	0.4	0.5	0.7	0.4	10.0
1979	100.0	1.1	1.4	0.5	0.6	0.8	0.4	7.7
1980	108.8	1.3	1.6	0.5	0.6	0.9	0.5	6.8
1981	116.9	1.1	1.7	0.6	0.6	0.9	0.3	12.1
1982	130.1	1.3	1.9	0.7	0.6	0.9	0.3	10.6
1983	142.0	1.3	2.0	0.7	0.7	1.0	0.3	3.9
1984	147.2	1.4	2.1	0.7	0.8	1.1	0.3	6.1
1985	154.7	1.6	2.3	0.8	0.8	1.2	0.4	6.3
1986	162.5	1.6	2.4	0.8	1.0	1.3	0.4	14.9
1987	179.0	1.7	2.6	0.9	1.0	1.4	0.4	6.8
1988	187.4	1.8	2.8	0.9	1.2	1.7	0.3	14.0
1989	203.1	1.9	3.1	1.0	1.3	1.7	0.2	10.7
1990	215.8	2.8	3.4	1.1	1.4	1.8	0.8	10.8
1991	229.4	3.2	3.5	1.1	1.5	1.8	1.1	11.5
1992	244.1	3.7	3.6	1.3	1.6	1.9	1.6	3.2
1993	251.1	3.3	3.6	1.3	1.7	2.1	1.3	2.6
1994	257.0	3.4	3.6	1.3	1.7	2.1	1.6	9.6
1995	270.0	3.4	3.6	1.4	1.8	2.2	1.6	14.5
1996	288.0	3.4	3.8	1.5	1.9	2.3	1.5	3.4
1997	294.8	3.7	3.9	1.5	2.0	2.6	1.9	16.0
1998	314.5	4.1	4.1	1.5	2.1	2.6	2.0	13.4
1999	332.0	3.6	4.3	1.7	2.3	2.8	1.5	2.8
2000	338.5	4.1	4.6	1.6	2.4	3.3	2.0	22.9
2001	365.4	3.3	4.9	1.8	2.5	3.3	1.1	13.1
2002	381.9	3.7	5.0	1.9	2.6	3.5	1.4	17.5
2003	403.1	3.4	5.4	1.8	2.9	4.0	0.9	19.5
2004	426.0	3.8	5.6	2.0	2.9	3.7	1.0	13.8
2005	443.7	3.9	5.9	2.2	3.2	3.9	1.0	14.8
2006	462.5	5.1	6.3	2.1	3.2	4.1	1.8	23.0
2007	490.6	4.1	6.6	2.4	3.3	4.1	0.7	4.7
2008	499.4	3.9	6.6	2.3	3.5	4.7	0.8	21.3
2009	524.6	4.8	6.8	2.4	3.6	4.8	1.7	11.4
2010	540.8	3.5	6.6	2.5	3.7	4.9	0.6	-2.9
2011	541.4	4.4	6.4	2.5	4.0	5.5	1.9	18.8
2012	564.6	4.0	6.6	2.8	4.0	5.3	1.6	14.7
2013	583.3	4.4	6.8	2.9	4.3	5.6	1.8	

Table A6. Non-market human capital, 1975-2013
In constant 2013 dollars (trillions)

		Net human capital investment					
Year	Stock	Total	Births	Deaths	Education	Aging	Residual
1975	392.8	4.7	5.4	2.1	3.3	3.1	1.2
1976	397.4	4.1	5.5	2.1	3.2	3.2	0.8
1977	401.5	4.2	5.7	2.1	3.2	3.3	0.6
1978	405.6	4.3	5.7	2.1	3.2	3.4	1.0
1979	410.0	4.5	6.0	2.1	3.1	3.5	1.0
1980	414.5	4.9	6.2	2.2	3.1	3.5	1.2
1981	419.3	4.1	6.3	2.2	3.1	3.5	0.4
1982	423.4	4.2	6.3	2.2	3.1	3.5	0.5
1983	427.6	4.0	6.3	2.2	3.1	3.5	0.3
1984	431.6	4.1	6.3	2.2	3.1	3.5	0.4
1985	435.7	4.5	6.5	2.3	3.0	3.6	0.8
1986	440.2	4.2	6.5	2.3	3.0	3.6	0.6
1987	444.4	4.1	6.6	2.3	3.1	3.7	0.5
1988	448.5	4.2	6.7	2.4	3.1	3.7	0.4
1989	452.7	4.3	7.0	2.4	3.2	3.6	0.2
1990	457.0	6.0	7.2	2.4	3.3	3.6	1.6
1991	463.0	6.6	7.1	2.4	3.3	3.6	2.2
1992	469.5	7.2	7.0	2.4	3.4	3.7	2.8
1993	476.7	6.1	6.9	2.5	3.5	3.8	2.1
1994	482.9	6.7	6.8	2.5	3.5	4.0	2.8
1995	489.5	6.3	6.7	2.5	3.5	4.1	2.8
1996	495.8	5.8	6.7	2.5	3.5	4.2	2.3
1997	501.7	6.5	6.7	2.5	3.6	4.4	3.1
1998	508.2	6.6	6.8	2.5	3.6	4.4	3.1
1999	514.8	5.6	6.8	2.6	3.7	4.6	2.3
2000	520.4	6.2	7.0	2.6	3.7	4.6	2.6
2001	526.5	4.7	6.9	2.6	3.8	4.6	1.2
2002	531.2	5.1	6.9	2.7	3.9	4.6	1.6
2003	536.4	4.6	7.0	2.7	3.9	4.6	0.9
2004	541.0	4.9	7.1	2.6	3.9	4.6	1.2
2005	545.9	4.8	7.1	2.7	3.9	4.7	1.1
2006	550.7	6.0	7.3	2.7	4.0	4.7	2.1
2007	556.6	4.6	7.4	2.7	4.1	4.8	0.6
2008	561.2	4.5	7.3	2.7	4.1	5.0	0.7
2009	565.7	5.4	7.1	2.7	4.3	5.0	1.6
2010	571.0	3.6	6.9	2.7	4.4	5.2	0.3
2011	574.6	4.7	6.8	2.8	4.3	5.4	1.8
2012	579.3	4.0	6.8	2.8	4.2	5.5	1.3
2013	583.3	4.4	6.8	2.9	4.3	5.6	1.8

Table A7. Active market human capital, 1975-2013
In current dollars (trillions)

		Net human capital investment							
Year	Stock	Total	Births	Deaths	Education	Aging	Transfer	Residual	Revaluation
1975	23.6	0.7	0.0	0.1	0.3	0.7	1.1	0.1	1.7
1976	26.0	0.6	0.0	0.1	0.4	0.7	1.1	0.0	2.0
1977	28.6	0.6	0.0	0.1	0.4	0.8	1.2	0.0	2.5
1978	31.7	0.7	0.0	0.1	0.4	0.9	1.2	0.0	3.1
1979	35.5	0.7	0.0	0.1	0.4	1.0	1.3	0.0	2.3
1980	38.5	0.8	0.0	0.1	0.5	1.1	1.3	0.2	2.9
1981	42.2	0.6	0.0	0.1	0.5	1.2	1.4	0.0	1.9
1982	44.7	0.6	0.0	0.1	0.6	1.3	1.4	-0.1	2.4
1983	47.6	0.7	0.0	0.1	0.6	1.4	1.6	-0.1	2.9
1984	51.2	0.6	0.0	0.1	0.6	1.5	1.8	-0.2	2.8
1985	54.6	0.8	0.0	0.1	0.7	1.6	1.8	0.0	3.3
1986	58.7	0.6	0.0	0.2	0.7	1.7	1.8	0.0	2.4
1987	61.8	0.4	0.0	0.2	0.8	1.8	1.8	-0.2	3.0
1988	65.2	0.5	0.0	0.2	0.8	1.9	1.9	-0.1	4.7
1989	70.3	0.3	0.0	0.2	0.9	2.1	2.1	-0.3	1.2
1990	71.9	0.6	0.0	0.2	0.9	2.2	2.1	-0.1	0.5
1991	73.0	0.9	0.0	0.2	1.0	2.3	2.3	0.0	1.3
1992	75.2	1.1	0.0	0.2	1.0	2.4	2.4	0.2	1.9
1993	78.2	1.3	0.0	0.2	1.1	2.5	2.6	0.3	3.1
1994	82.6	1.4	0.0	0.2	1.1	2.7	2.7	0.5	2.3
1995	86.4	1.2	0.0	0.2	1.2	2.8	2.7	0.4	4.4
1996	92.0	1.5	0.0	0.2	1.2	3.0	3.0	0.5	5.7
1997	99.2	1.4	0.0	0.2	1.4	3.3	3.1	0.4	3.9
1998	104.4	1.4	0.0	0.3	1.4	3.5	3.2	0.6	6.6
1999	112.4	1.1	0.0	0.3	1.6	3.8	3.6	0.0	3.4
2000	116.9	1.5	0.0	0.3	1.5	3.9	3.7	0.5	3.6
2001	122.0	0.9	0.0	0.3	1.7	4.2	3.9	-0.2	4.6
2002	127.5	1.8	0.0	0.3	1.8	4.3	4.2	0.4	3.0
2003	132.3	1.0	0.0	0.3	1.9	4.5	4.5	-0.5	2.3
2004	135.7	1.5	0.0	0.3	1.9	4.6	4.5	0.0	5.9
2005	143.0	1.4	0.0	0.4	1.9	4.8	4.7	-0.2	5.9
2006	150.3	1.8	0.0	0.4	2.1	5.1	4.9	0.3	4.9
2007	157.0	1.0	0.0	0.4	2.2	5.2	5.0	-0.6	2.6
2008	160.6	0.7	0.0	0.4	2.4	5.5	4.9	-0.8	-1.9
2009	159.4	1.6	0.0	0.4	2.6	5.5	5.1	-0.1	1.8
2010	162.8	1.0	0.0	0.4	2.6	5.6	5.0	-0.7	4.4
2011	168.1	1.9	0.0	0.4	2.8	5.8	5.1	0.2	0.2
2012	170.2	1.6	0.0	0.4	2.7	5.9	5.0	0.2	3.9
2013	175.7	2.0	0.0	0.4	2.8	6.1	5.1	0.6	

Table A8. Active market capital, 1975-2013
In constant 2013 dollars (trillions)

		Net human capital investment						
Year	Stock	Total	Births	Deaths	Education	Aging	Transfer	Residual
1975	107.9	3.3	0.0	0.3	1.7	3.4	5.6	-0.2
1976	111.1	2.7	0.0	0.3	1.6	3.6	5.5	-0.5
1977	113.8	2.5	0.0	0.3	1.6	3.7	5.5	-0.6
1978	116.3	2.5	0.0	0.3	1.6	3.8	5.3	-0.4
1979	118.8	2.2	0.0	0.3	1.6	3.8	5.0	-0.3
1980	121.0	2.4	0.0	0.4	1.7	3.8	4.6	0.3
1981	123.4	1.8	0.0	0.3	1.7	3.9	4.6	-0.2
1982	125.2	1.6	0.0	0.3	1.7	3.9	4.6	-0.5
1983	126.8	1.8	0.0	0.3	1.7	3.9	4.8	-0.5
1984	128.6	1.6	0.0	0.3	1.7	3.9	4.9	-0.7
1985	130.2	1.9	0.0	0.4	1.7	4.0	4.8	-0.2
1986	132.0	1.4	0.0	0.4	1.7	4.0	4.4	-0.3
1987	133.4	1.0	0.0	0.4	1.7	4.1	4.3	-0.6
1988	134.4	1.0	0.0	0.4	1.7	4.1	4.2	-0.5
1989	135.4	0.6	0.0	0.4	1.8	4.1	4.1	-0.8
1990	136.0	1.1	0.0	0.4	1.8	4.1	4.1	-0.3
1991	137.1	1.6	0.0	0.4	1.9	4.1	4.3	-0.1
1992	138.7	2.1	0.0	0.4	2.0	4.2	4.4	0.4
1993	140.8	2.2	0.0	0.4	2.0	4.3	4.6	0.4
1994	143.1	2.5	0.0	0.4	1.9	4.5	4.8	0.8
1995	145.6	2.1	0.0	0.4	1.9	4.7	4.8	0.6
1996	147.7	2.4	0.0	0.4	1.9	4.8	5.0	0.7
1997	150.1	2.1	0.0	0.4	2.0	4.9	4.9	0.5
1998	152.2	2.1	0.0	0.4	2.0	5.0	4.8	0.7
1999	154.3	1.5	0.0	0.4	2.1	5.2	5.1	-0.1
2000	155.8	2.0	0.0	0.4	2.1	5.2	5.0	0.5
2001	157.8	1.2	0.0	0.4	2.2	5.3	5.1	-0.4
2002	158.9	2.2	0.0	0.4	2.3	5.3	5.3	0.4
2003	161.2	1.3	0.0	0.4	2.4	5.3	5.4	-0.7
2004	162.4	1.8	0.0	0.4	2.3	5.4	5.3	-0.1
2005	164.2	1.6	0.0	0.4	2.4	5.4	5.4	-0.3
2006	165.7	2.0	0.0	0.4	2.4	5.5	5.2	0.2
2007	167.7	1.0	0.0	0.4	2.5	5.6	5.2	-0.7
2008	168.8	0.7	0.0	0.4	2.6	5.7	5.0	-0.9
2009	169.5	1.7	0.0	0.4	2.8	5.6	5.1	-0.1
2010	171.1	1.0	0.0	0.4	2.9	5.7	5.0	-0.7
2011	172.2	1.9	0.0	0.4	2.8	5.8	5.1	0.2
2012	174.1	1.6	0.0	0.4	2.7	6.0	5.1	0.1
2013	175.7	2.0	0.0	0.4	2.8	6.1	5.1	0.6

Table A9. Nascent market human capital, 1975-2013
In current dollars (trillions)

		Net human capital investment							
Year	Stock	Total	Births	Deaths	Education	Aging	Transfer	Residual	Revaluation
1975	11.4	-0.2	0.6	0.0	0.2	0.0	1.1	0.1	0.6
1976	11.8	-0.2	0.6	0.0	0.2	0.0	1.1	0.1	0.9
1977	12.5	-0.2	0.7	0.0	0.2	0.0	1.2	0.1	0.9
1978	13.2	-0.2	0.7	0.0	0.3	0.0	1.2	0.1	1.3
1979	14.3	-0.1	0.8	0.0	0.3	0.0	1.3	0.0	1.3
1980	15.5	0.0	0.9	0.0	0.3	-0.1	1.3	0.1	1.1
1981	16.7	0.0	1.0	0.0	0.3	0.0	1.4	0.1	1.0
1982	17.7	0.1	1.1	0.0	0.3	-0.1	1.4	0.1	1.2
1983	19.0	0.0	1.1	0.0	0.3	-0.1	1.6	0.0	1.7
1984	20.6	0.0	1.3	0.0	0.3	-0.1	1.8	0.1	0.7
1985	21.4	0.0	1.3	0.0	0.4	0.0	1.8	0.0	1.4
1986	22.8	0.2	1.4	0.0	0.4	0.0	1.8	0.1	1.3
1987	24.3	0.3	1.5	0.0	0.5	0.0	1.8	0.1	1.1
1988	25.7	0.3	1.6	0.0	0.5	0.0	1.9	0.1	3.0
1989	29.0	0.5	1.9	0.0	0.5	-0.1	2.1	0.2	1.1
1990	30.7	0.7	2.0	0.0	0.5	-0.1	2.1	0.2	1.1
1991	32.5	0.5	2.0	0.0	0.6	-0.1	2.3	0.2	1.2
1992	34.2	0.7	2.1	0.0	0.7	0.0	2.4	0.4	0.1
1993	35.0	0.4	2.0	0.0	0.7	0.0	2.6	0.2	-0.1
1994	35.3	0.2	2.0	0.0	0.7	0.0	2.7	0.2	0.0
1995	35.5	0.5	2.0	0.0	0.8	0.0	2.7	0.5	1.8
1996	37.8	-0.2	2.1	0.0	0.8	0.0	3.0	-0.1	2.9
1997	40.5	0.4	2.3	0.0	0.9	0.1	3.1	0.5	1.5
1998	42.4	0.2	2.4	0.0	0.9	0.0	3.2	0.2	1.9
1999	44.6	0.2	2.5	0.0	1.0	0.1	3.6	0.4	2.1
2000	46.8	0.3	2.7	0.0	1.0	0.0	3.7	0.4	2.9
2001	50.1	0.1	2.8	0.0	1.0	-0.1	3.9	0.2	1.7
2002	51.9	-0.5	2.9	0.0	1.1	0.0	4.2	-0.2	2.4
2003	53.7	0.1	3.1	0.0	1.1	0.0	4.5	0.5	1.0
2004	54.8	-0.2	3.2	0.0	1.1	0.0	4.5	0.0	1.9
2005	56.6	-0.2	3.3	0.0	1.1	0.0	4.7	0.1	3.7
2006	60.1	0.0	3.6	0.0	1.1	-0.1	4.9	0.0	2.0
2007	62.1	0.1	3.8	0.0	1.2	-0.1	5.0	0.0	0.7
2008	62.8	0.4	3.8	0.0	1.3	0.0	4.9	0.4	0.8
2009	64.1	0.8	3.7	0.0	1.4	0.1	5.1	0.9	-1.8
2010	63.0	-0.3	3.4	0.0	1.5	0.2	5.0	0.0	-1.0
2011	61.7	-0.1	3.3	0.0	1.6	0.3	5.1	0.5	-0.1
2012	61.5	0.1	3.3	0.0	1.4	0.2	5.0	0.5	2.2
2013	63.7	-0.2	3.5	0.0	1.4	0.1	5.1	0.2	

Table A10. Nascent market capital, 1975-2013
In constant 2013 dollars (trillions)

		Net human capital investment						
Year	Stock	Total	Births	Deaths	Education	Aging	Transfer	Residual
1975	57.8	-1.0	2.8	0.1	1.4	-0.1	5.6	0.4
1976	56.8	-0.8	2.8	0.1	1.4	-0.1	5.5	0.5
1977	56.0	-0.9	2.9	0.1	1.4	-0.1	5.5	0.3
1978	55.1	-0.7	2.9	0.1	1.3	-0.1	5.3	0.4
1979	54.3	-0.5	3.1	0.1	1.3	-0.1	5.0	0.2
1980	53.9	0.2	3.2	0.1	1.2	-0.1	4.6	0.3
1981	54.0	0.1	3.2	0.1	1.2	-0.1	4.6	0.2
1982	54.1	0.3	3.2	0.1	1.2	-0.2	4.6	0.4
1983	54.4	-0.1	3.2	0.1	1.2	-0.2	4.8	0.2
1984	54.3	0.1	3.2	0.1	1.2	-0.2	4.9	0.4
1985	54.4	-0.1	3.3	0.1	1.2	-0.1	4.8	0.1
1986	54.3	0.5	3.3	0.1	1.2	-0.1	4.4	0.3
1987	54.8	0.7	3.4	0.1	1.2	-0.1	4.3	0.3
1988	55.4	0.7	3.4	0.1	1.2	-0.1	4.2	0.2
1989	56.1	1.0	3.5	0.1	1.2	-0.1	4.1	0.3
1990	57.1	1.3	3.6	0.1	1.2	-0.2	4.1	0.4
1991	58.4	1.0	3.6	0.1	1.3	-0.1	4.3	0.3
1992	59.4	1.2	3.6	0.1	1.3	-0.1	4.4	0.7
1993	60.6	0.6	3.5	0.1	1.3	-0.1	4.6	0.4
1994	61.2	0.4	3.5	0.0	1.3	-0.1	4.8	0.3
1995	61.6	0.9	3.4	0.0	1.4	0.0	4.8	0.9
1996	62.5	-0.4	3.4	0.0	1.4	0.0	5.0	-0.1
1997	62.1	0.6	3.4	0.0	1.4	0.0	4.9	0.7
1998	62.7	0.3	3.5	0.0	1.4	0.0	4.8	0.4
1999	63.0	0.2	3.5	0.0	1.4	0.0	5.1	0.5
2000	63.2	0.4	3.6	0.0	1.4	0.0	5.0	0.5
2001	63.7	0.1	3.5	0.0	1.4	-0.1	5.1	0.3
2002	63.8	-0.7	3.5	0.0	1.4	0.0	5.3	-0.3
2003	63.1	0.2	3.6	0.0	1.4	0.0	5.4	0.6
2004	63.3	-0.2	3.6	0.0	1.4	-0.1	5.3	0.0
2005	63.1	-0.2	3.6	0.0	1.4	0.0	5.4	0.1
2006	62.8	0.0	3.7	0.0	1.4	-0.1	5.2	0.0
2007	62.8	0.1	3.8	0.0	1.4	-0.1	5.2	0.0
2008	62.9	0.5	3.7	0.0	1.4	0.0	5.0	0.4
2009	63.3	0.7	3.6	0.0	1.4	0.0	5.1	0.9
2010	64.1	-0.3	3.5	0.0	1.4	0.1	5.0	0.0
2011	63.8	-0.1	3.5	0.0	1.4	0.2	5.1	0.5
2012	63.7	0.1	3.5	0.0	1.4	0.1	5.1	0.5
2013	63.7	-0.2	3.5	0.0	1.4	0.1	5.1	0.2