Human Capital Accounting in the United States: 1994 to 2006

Michael S. Christian
Wisconsin Center for Education Research

Preliminary: Do not cite or circulate.

Abstract

This paper presents measures of the human capital stock and of investment in human capital for the United States between 1994 and 2006. When both market and non-market production are included, the stock of human capital was equal to about three quarters of a quadrillion dollars in 2006, of which about 70 percent was non-market. The account breaks down human capital investment among the effects of births, deaths, aging, and education on human capital, as well as a residual effect attributed to (unmeasured) migration. Measures of gross investment in education are found to be very sensitive to counterfactual assumptions; consequently, investment in education is measured net of aging.

Introduction

Human capital accounting is simultaneously one of the easiest and most difficult exercises in empirical economics. It is easy in the sense that the statistical techniques necessary are relatively simple. On the other hand, getting the data right can be massive challenge. The data available do not always include all of the variables at the level of detail one needs. This necessitates imputations and simplifications that may interplay with the assumptions of the model in interesting and not entirely welcome ways.

The sections that follow present a human capital account for the United States from 1994 to 2006. Its methods are borrowed heavily from Jorgenson and Fraumeni (1989, 1992), although it deviates in some aspects. Its primary source of data is the Current Population Survey (CPS), with substantial imputations to account for changes in the measurement of education in the survey. Like previous human capital accounts, it finds that the stock of human capital is very large--nearly three-quarters of a quadrillion dollars in 2006 if both its market and non-market components are included. The account is not entirely satisfactory because it does not measure gross investment in education, but rather investment in education net of aging of enrolled persons. A discussion of gross investment in education, its sensitivity to different assumptions about enrollment patterns, and how that sensitivity may in part be a result of the approach to constructing the data set concludes the paper.

Creating an Analysis Data Set for Human Capital Accounting

The central data set used in producing the human capital account is the October school enrollment and March demographic supplements to the Current Population

Survey. From these data, nearly all of the information needed to produce an analysis data set suitable for producing a human capital account is available.

Population and School Enrollment

The October CPS is used to measure the population and school enrollment components of the analysis data set. This part of the data set includes population and school enrollment rates by age, sex, and individual year of education for persons ages 0 to 34 for each year between 1994 and 2006. It also includes population by age, sex, and membership in one of five broad education categories (no high school diploma, high school diploma, some college, bachelor's degree, and advanced degree) for persons ages 35 and older. The greater detail in the data set for persons ages 0 to 34 is a result of this group being of school-going age; it is necessary to measure their educational attainment by the individual year to account for their investment in education from school enrollment. It is presumed that persons age 35 and older are past school-going age; age is topcoded at 80.

A change in the basic CPS survey in 1993 makes the measurement of educational progress by individual year of education particularly challenging. Before 1993, the basic monthly CPS survey asked persons for the number of individual years of education they had completed: a number between zero and eighteen. Starting in 1993, the CPS switched to a different set of education categories that focused more on degrees and certifications earned, such as "high school graduate", "some college but no degree", and "bachelor's degree". An informative discussion of this switch is in Jaeger (1997). Since this switch, it is no longer possible to measure the distribution of persons in the population by individual years of education with a simple frequency count. Instead, this distribution must be imputed.

The distribution of persons by individual years of education is imputed using data from the October CPS school enrollment variables. The October CPS school enrollment supplement includes information about whether students were enrolled in school, whether enrolled full-time or part-time, and in which individual grade or year of school the person was enrolled. The school enrollment variables in the October supplement make it possible to plausibly guess the number of years of education completed by persons who are enrolled in school: one can realistically assume that a person who is enrolled in a particular year of school has completed education up to the year before. The school enrollment variables are also useful in guessing the distribution of the individual years of education of persons who are not enrolled in school. In some cases, it is realistic to assume that the distribution of individual years of education of persons who are not enrolled in school is the same as that of persons who are enrolled in school, conditional on age, sex, and measurable educational attainment. In other cases, historical data on enrollments going backward into the past for a particular cohort can be used to guess the distribution of individual years of education of persons in that cohort at a given time. For example, suppose we wanted to know how the distribution of 34-year-olds in 1994 who have completed either thirteen, fourteen or fifteen years of education breaks down by individual year of education. Using data from past October CPS supplements, we can estimate the total number of persons in the 1960 birth cohort who ever enrolled in each of the thirteenth, fourteenth, fifteenth, and sixteenth year of education at any time from 1968 (the first year of publicly available October CPS data) to the present (in this example, 1994). We can then guess the shares of persons who have completed between thirteen and fifteen years of education by individual year using the following approach:

$$\text{Share with 13 years education} = \frac{\text{All-time 13th year enrollment} - \text{All-time 14th year enrollment}}{\text{All-time 13th year enrollment} - \text{All-time 16th year enrollment}}$$

$$\text{Share with 14 years education} = \frac{\text{All-time 14th year enrollment} - \text{All-time 15th year enrollment}}{\text{All-time 13th year enrollment} - \text{All-time 16th year enrollment}}$$

$$\text{Share with 15 years education} = \frac{\text{All-time 15th year enrollment} - \text{All-time 16th year enrollment}}{\text{All-time 13th year enrollment} - \text{All-time 16th year enrollment}}$$

In the actual analysis, what is summed across years is not the number of persons in a birth cohort who enrolled in a grade, but rather the yearly shares of persons in a birth cohort who enrolled in a grade; this helps keep the estimation robust to changes in the approach to weighting in the CPS. A substantial amount of smoothing is also employed to keep the year-to-year variance in the shares of population by individual years of education under control. One possible problem with this approach is the "rose-colored-glasses" effect; people may report levels of education that are greater than that implied by their actual education histories, which could lead to different results depending on whether one uses reported education levels or education levels imputed from education histories (Fraumeni, 2000). The approach also assumes that migration or differential rates of births and deaths do not substantially alter the educational composition of birth cohorts over time. Details on the imputation of the distribution of the population by individual year of education are available in the Appendix.

Imputing the distribution of the school-going population by individual years of education restores some but not all of the information that one would have were there still a variable in the basic CPS that measures individual years of education. For example, it does not allow us to take into account differences in yearly earnings by individual year of education; to do that, we would need the distribution by individual year of education of earnings, as well as that of the population over age 35. The account presumes instead that the relationship between education and earnings in a given year is one in which earnings per work hour are the same within five broad education categories: no high school diploma, high school diploma, some college, bachelor's degree, and advanced degree.

Imputing the distribution of persons of school-going age across individual years of education does allow us to take into account how close persons of school-going age are to finishing their diplomas and degrees. It also allows us to value their school enrollment decisions by the extent that it brings them even closer. As a result, in this human capital account, there are large direct payoffs to finishing degrees and diplomas and no direct payoffs to finishing the intermediate non-degree years of education in between. Even so, investment in education has value even in non-degree years since each year of schooling moves a person one year closer to a degree, increasing the probability of earning the degree's payoff.

Earnings, Wages, Hours of Work, and Hours of Leisure

The March CPS is used to measure the labor and earnings components of the data set. Average earnings, average hours of work, and the average post-tax wage are measured by age, sex, and broad education category (no high school, high school, some college, bachelor's degree, advanced degree) for the years 1994 to 2006. The post-tax wage is measured by dividing earnings by hours, multiplying the result by 1 minus the marginal tax rate, and bounding that result between \$1 and \$50; when it is averaged by year, age, sex, and education, it is averaged across workers only.

This data can be merged directly into the October CPS-based population data for persons age 35 and older, who are also differentiated by year, age, sex, and the five broad education categories. However, some extra work is needed to merge this data to the October CPS-based population data for persons age 34 and younger, who are differentiated by individual year of education. To make this merge, the distribution of total hours of work across individual years of education within the five broad education categories was imputed using the distribution of hours worked in the previous week (a variable available in the basic CPS survey) by population and school enrollment. Earnings per hour of work were assumed to be the same within year, age, sex, and each of the five education categories, so imputing hours of work imputes earnings proportionally across individual years of education. Post-tax wage was also assumed to be the same within year, age, sex, and each of the five education categories.

Measuring Births, Deaths, Education, Aging, and Migration

At this point, the data set contains the following variables, each within year, age, sex, and education, and (with the exception of death rates) drawn entirely from the CPS:

pcount	Population.
ecount	Enrollment. Part-time enrollments are considered the equivalent of one-third of a full-time enrollment.
rate	Enrollment rate. Equals *pcount* ÷ *ecount*.
pcearnings	Average yearly earnings per person.
pchours	Average yearly work hours per person.
pcschoolhours	Average yearly hours in school per person. 1300 × *rate*.
pcfreehours	Average yearly leisure hours per person. 5110 - *pchours* - *pcschoolhours*.
pcfreevalue	Average value of yearly leisure hours per person. Equals *pcfreehours* times the post-tax wage rate.
d	Death rate, from the life tables of the Centers for Disease Control. Only differentiated by age and sex.

From these data, changes in population can be broken down among births, deaths, aging, education, and migration. The variables that measure these shifts are computed as below:

pcountdead	Total deaths by year, age, sex, and education. Equals $pcount \times d$.
pcountnotdead	Total survivors by year, age, sex, and education. Equals $pcount - pcountdead$.
pcountborn	Births by year and sex. Equal to population of age zero by sex in the following year. Only has non-zero value for cells where age is zero.
pcountedshift	Change in population from the current year to the following year due to schooling and aging of people who were enrolled in school. Equal to $pcountnotdead_{y,a-1,s,e-1} \times rate_{y,a-1,s,e-1} - pcountnotdead_{y,a,s,e} \times rate_{y,a,s,e}$, where y is year, a is age, s is sex, and e is level of education by single year.
pcountageshift	Change in population from the current year to the following year due to aging of people who were not enrolled in school. Equal to $pcountnotdead_{y,a-1,s,e} \times (1 - rate_{y,a-1,s,e}) - pcountnotdead_{y,a,s,e} \times (1 - rate_{y,a,s,e})$.
pcountmig	Change in population from one year to the next that cannot be explained with births, deaths, aging, or education. Equal to $pcount_{y+1,a,s,e} - pcountnotdead_{y,a,s,e} - pcountborn_{y,a,s,e} - pcountedshift_{y,a,s,e} - pcountageshift_{y,a,s,e}$.

Two especially important things are worth noting about the construction of these variables. First, the shift in population due to education includes both the effect of schooling and the effect of aging among those enrolled in school. The effect of this shift in population on human capital is a measure of *net* human capital investment that measures the investment in human capital from education net of the depreciation in human capital from the aging of those enrolled in school. Second, the shift in population due to migration is not a direct measure of migration, but rather a residual: all changes in population that cannot be attributed to births, deaths, education, or aging is attributed to migration.

The CPS's approach to weighting observations can sometimes lead to substantial swings in population estimates from year to year.[1] To account for this, the CPS-based data were adjusted to conform to national aggregates from alternative sources: population to match estimates from the Bureau of the Census; enrollment to match estimates from the Common Core of Data, the Private School Universe Survey, and the Integrated Postsecondary Education Data System; and births and deaths to match vital statistics data from the National Center for Health Statistics. The adjustments were made by computing simple ratios of the national aggregates from the alternative data to the national aggregates implied by the CPS-based data and multiplying all appropriate variables by those ratios; nearly all of the alternative data used to make the adjustments was available in either the *Statistical Abstract of the United States* or the *Digest of Education Statistics*.

Measuring Human Capital and Human Capital Investment

With the analysis data set assembled, the work of producing a human capital account begins. Much of the steps in producing a human capital account are borrowed heavily from the accounts of Jorgenson and Fraumeni (1989, 1992).

Per Capita Human Capital

The human capital stock is equal to the lifetime labor incomes--market and nonmarket--of the entire U.S. population. The first step in measuring this stock is measuring average lifetime labor income by year, age, sex, and education, which could also be understood as a measure of per capita human capital. Per capita human capital by year, age, sex, and education is measured starting with the oldest age group and moving

[1] For a discussion of changes in weighting in the CPS, see the "Historical Comparability" section of the Bureau of Labor Statistics' CPS documentation at <http://www.bls.gov/cps/eetech_methods.pdf>.

backward. Per capita market human capital for the oldest age group in the data set--the age 80 and older group--is measured as follows:

$$pcmhc_{y,80+,s,e} = [1 - (1+\rho)^{-1}(1-d_{y,80+,s,e})(1+g)]^{-1} pcearnings_{y,80+,s,e}$$

where $pcmhc_{y,80+,s,e}$ is per capita market human capital in year y of persons age 80 and older of sex s and education e, ρ is the yearly discount rate, and g is the yearly rate of income growth.[2] Per capita market human capital is equal to the present discounted value of expected lifetime market labor income of a person age 80 or older, conditional on constant discount, income growth, and death rates. Its non-market equivalent--which is based not on earnings but on the value of leisure time--is measured as:

$$pcnhc_{y,80+,s,e} = [1 - (1+\rho)^{-1}(1-d_{y,80+,s,e})(1+g)]^{-1} pcfreevalue_{y,80+,s,e}$$

where $pcmhc_{y,80+,s,e}$ is per capita nonmarket human capital in year y of persons age 80 and older of sex s and education e.

From the oldest age group, one can work backwards to measure the human capital of persons one year younger. Between the ages of 35 and 79, it is presumed that persons do not enroll in school; consequently, there is no need to account for persons moving up to higher levels of education. Per capita human capital in these age groups is measured rather simply as:

$$pcmhc_{y,a,s,e} = pcearnings_{y,a,s,e} + (1+\rho)^{-1}(1-d_{y,80+,s,e})(1+g)pcmhc_{y,a+1,s,e}$$
$$pcnhc_{y,a,s,e} = pcfreevalue_{y,a,s,e} + (1+\rho)^{-1}(1-d_{y,80+,s,e})(1+g)pcnhc_{y,a+1,s,e}$$

At these ages, per capita human capital is equal to earnings in the current year plus an expectation of per capita human capital in the following year, taking into account aging and rates of death, time preference, and income growth.

[2] This approach to handling persons age 80 and over is different from that of Jorgenson and Fraumeni, which sets the human capital of persons above a particular age threshold at zero.

Between the ages of 5 and 34, it is possible to enroll in school and move up to a higher level of education. Per capita human capital in these age groups is measured as:

$$pcmhc_{y,a,s,e} = pcearnings_{y,a,s,e}$$
$$+ [(1+\rho)^{-1}(1\text{-}d_{y,80+,s,e})(1+g)][rate_{y,a,s,e}pcmhc_{y,a+1,s,e+1} + (1\text{-}rate_{y,a,s,e})pcmhc_{y,a+1,s,e}]$$
$$pcnhc_{y,a,s,e} = pcfreevalue_{y,a,s,e}$$
$$+ [(1+\rho)^{-1}(1\text{-}d_{y,80+,s,e})(1+g)][rate_{y,a,s,e}pcnhc_{y,a+1,s,e+1} + (1\text{-}rate_{y,a,s,e})pcnhc_{y,a+1,s,e}]$$

This is the same as that for the older age groups, except that now expectations of per capita human capital in the following year includes the likelihood of school enrollment as well as aging, death, time preference, and income growth. For ages below 15, earnings is set to zero, as is the value of leisure time, so all human capital derives from expectations of future earnings and values of leisure time.

Finally, between the ages of zero and 4, it is not possible to enroll in school. For this group, per capita human capital is set the same way as it is for those between the ages of 35 and 79, except that earnings and value of leisure time are set to zero. Education is also set to the lowest education group of no education.

The Human Capital Stock, Net Human Investment, and Revaluation

The human capital stock is measured by taking the weighted sum of the population within years across sex, age, and education using per capita human capital by year, sex, age, and education as a weight. In mathematical terms, this is equal to:

$$\text{Human capital stock in year } y = \sum_a \sum_s \sum_e \left(pcount_{y,a,s,e} \times pchc_{y,a,s,e}\right)$$

where *pchc* is the per capita human capital stock, the sum of its market (*pcmhc*) and non-market (*pcnhc*) components by year, age, sex, and education. The human capital stock is the total expected lifetime labor income--market and non-market--of the U.S. population.

Net investment in human capital is equal to the effects of changes from one year to the next in the U.S. population on the human capital stock. This includes changes in both the size and the distribution of the U.S. population, and is mathematically equal to:

$$\text{Net human investment} = \sum_a \sum_s \sum_e \left[\left(pcount_{y+1,a,s,e} - pcount_{y,a,s,e} \right) \times pchc_{y,a,s,e} \right]$$

Note that, in this model, expectations of future labor incomes are set using the distribution of earnings and values of leisure time across sex, age, and education within a single year. Each year, this distribution changes, which in turn means that expectations of future labor incomes change and the human capital stock is revalued. This revaluation is equal to:

$$\text{Revaluation} = \sum_a \sum_s \sum_e \left[pcount_{y+1,a,s,e} \times \left(pchc_{y+1,a,s,e} - pchc_{y,a,s,e} \right) \right]$$

The dynamic relationship among the human capital stock, human investment, and revaluation is a simple additive one: this year's human capital stock plus net human investment plus revaluation is equal to next year's human capital stock.

Breaking Down Net Human Investment Into Its Components

Net human investment is the effect of changes in the size and distribution of the population on the human capital stock. This account breaks net human investment into five components: investment from births, depreciation from deaths, net investment from education and aging of persons enrolled in school, depreciation from aging of persons not enrolled in school, and net investment from migration. These five components are measured mathematically as follows:

$$\text{Investment from births} = \sum_a \sum_s \sum_e \left(pcountborn_{y,a,s,e} \times pchc_{y,a,s,e} \right)$$

Depreciation from deaths = $\sum_a \sum_s \sum_e \left(pcountdead_{y,a,s,e} \times pchc_{y,a,s,e} \right)$

Net investment from education and aging of persons enrolled in school =

$$= \sum_a \sum_s \sum_e \left(pcountedshift_{y,a,s,e} \times pchc_{y,a,s,e} \right)$$

Deprecation from aging of persons not enrolled in school =

$$= \sum_a \sum_s \sum_e \left(pcountageshift_{y,a,s,e} \times pchc_{y,a,s,e} \right)$$

Net investment from migration = $\sum_a \sum_s \sum_e \left(pcountmig_{y,a,s,e} \times pchc_{y,a,s,e} \right)$

Of these components, the most substantial deviation from other human capital accounts is the decision to measure investment in education net of the aging of persons enrolled in school, rather than as gross investment in education. To illustrate the difference between investment in education net of aging and gross investment in education, consider an investment in education made by a single person: a 17-year-old with 11 years of education who enrolls in his 12th year of education. For this individual, investment in education net of aging is equal to the difference between this person's lifetime earnings before and after competing his 12th year of education. This difference includes both the effect of completing the 12th year of education and the effect of aging from age 17 to age 18, and is consequently the impact of investment in education net of aging. We assume that this difference is equal to the difference between the lifetime earnings of an 18-year-old with 12 years of education and a 17-year-old with 11 years of education. This assumption implies that 17-year-olds presently enrolled in their 12th year of education will, upon becoming 18-year-olds with 12 years of education in the following year, become similar to 18-year-olds with 12 years of education in the present. This seems like a safe assumption to make: essentially, it assumes that people who make specific choices in the present will become similar to those who have made similar choices in the past. When differences such as these are summed across all persons, the resulting measure is a total measure of investment in education net of the aging of those being educated. Although the assumptions underlying the net investment measure are relatively safe, the measure does have the disadvantage of not disentangling the effect of education from the effect of aging while being educated.

In contrast, a gross education investment measure isolates the impact of education from the impact of aging. For a single 17-year-old enrolled in the 12th year of education, gross investment in education is equal to the difference between one's lifetime earnings after completing the 12th year of education at age 18 and what one's lifetime earnings would have been had one reached age 18 without completing the 12th year of education.[3] When differences such as these are summed across all persons, the result is a gross measure of the value of investment in education: the difference between actual human capital in the present year and a counterfactual human capital in which no education was completed in the present year. To measure this difference, one needs to not only make assumptions about what people who enrolled in school will be like in the next year, but also assumptions about what people who enrolled in school would have been like in the next year had they not enrolled in school. The latter is a hard assumption to make. For example, suppose it is assumed that 17-year-olds who are enrolled in their 12th year of education will, in the next year, become like present-day 18-year-olds with 12 years of education but would, had they not enrolled in school, have become like present-day 18-year-olds with 11 years of education. Empirically, these are two very divergent paths;

[3] The measures of the output of education in Jorgenson and Fraumeni (1989) are slightly different from the measures that come from this counterfactual approach, which measures the effect of education after all of the other effects, such as aging, are taken into account. The Jorgenson-Fraumeni approach measures the effect of education before the other effects are taken into account. It measures the human capital stock against a counterfactual in which the education levels of all enrolled persons are instantaneously increased by one year.

while people who arrive at age 18 with 12 years of education are "on track" with regards to their education and are very likely to pursue further education, people who arrive at age 18 with 11 years of education have fallen "off track" and are considerably less likely to finish their diplomas, much less enroll in college and earn degrees. Using the differences in lifetime incomes between these two cases to measure the value of investment in the 12th year of education would imply an investment of very great value. In contrast, suppose it is assumed that 17-year-olds who enrolled in their 12th year of education, had they missed a year of schooling, would not have fallen "off track" and would have simply picked up where they left off the following year, enrolling in the 12th year of education at age 18 instead. Under this assumption, missing a year of school is just a delay in schooling with only small long-term implications, and so the value of investment in the 12th year of education is not nearly as large.

It happens that, in this particular account, measures of total gross investment in education in the U.S. are very sensitive to the assumptions one makes about the paths that people who are enrolled in school in the present year would have taken in the counterfactual case in which they had they not enrolled in school in the present year. In particular, it is sensitive to whether it is assumed that missing a year of school would have put them "off track" in their educations, like people who actually did miss a year of school, or if they would have stayed "on track" in their educations, pursuing the same educational trajectory with a year's lag. In the first case, the value of gross investment in education is extremely--in fact implausibly--large, while in the second case value of gross investment in education is much more modest.

In contrast, investment in education net of aging does not require counterfactual assumptions about what persons who did enroll in school would have done with their future educational plans had they not enrolled in school. As a result, it is safer to measure. It is certainly less interesting than gross educational investment because it doesn't tell us the actual impact of education itself, but instead of two things that necessarily happen together--education and aging. However, it is a more reliable measure given the data. The sensitivity of gross investment measures and possibilities for reducing that sensitivity are discussed at the conclusion of the paper.

The Human Capital Stock

The overall human capital stock between 1994 and 2006 is presented in Figure 1. In 2006, assuming a discount rate of 2 percent and an income growth rate of 4 percent, the total stock of human capital was $738 trillion. Of that $738 trillion, $536 trillion--71 percent--is the present discounted value of non-market, non-school leisure time, while the remaining $212 trillion is the present discounted value of lifetime market earnings. The human capital stock is overwhelming in size compared to the stock of physical assets, which had a value of $45 trillion in 2006.[4]

The share of the human capital stock that is non-market has remained very stable over the period between 1994 and 2006, fluctuating only very slightly between 71 percent and 72 percent. There is a very slight upward discontinuity in the size of non-market human capital in 2003 that is attributable to a temporary reduction in marginal tax rates, which increased the marginal value of time spent outside of work from a human capital perspective. The ratio of the value of the human capital stock to the value of physical

[4] The stock of physical assets is equal to the stock of fixed assets and consumer durable goods in Table 1.1 of the Bureau of Economic Analysis's Fixed Assets tables.

assets has also dropped over the period; while the human capital stock was about 19 times the size of the stock of physical assets in 1994, the ratio between the two was about 16 in 2006. Most of this drop is concentrated in the period between 2003 and 2006.

Figure 2 presents a time series of the human capital stock in real terms. The real human capital stock time series is a weighted index of the U.S. population over time. More specifically, it is a cost-weighted Fisher index of the U.S. population by age, sex, and education, using per capita human capital by age, sex, and education as the cost weight. Changes in this series over time can be attributed to changes in the size of the U.S. population and changes in the distribution of the U.S. population by age, sex, and education. Changes in per capita human capital for a particular age/sex/education group represent changes in cost, not in quantity, and are consequently not reflected in the real human capital stock.

The real human capital stock increased at an annual rate of 1.1 percent per year between 1994 and 2006. The non-market component grew at a slightly slower annual rate of 1.0 percent, while the market component grew at a slightly faster rate that nonetheless rounded down to 1.1 percent. Growth in the real human capital stock was faster in the 1994 to 2001 period than in the 2001 to 2006 period. Between 1994 and 2001, human capital grew at an annual rate of 1.2 percent, the non-market component grew at an annual rate of 1.1 percent, and the market component grew at an annual rate of 1.3 percent. Between 2001 and 2006, overall growth slowed to 0.9 percent rate, growth of the non-market component slowed to 0.7 percent, and growth of the market component slowed to 1.0 percent. Over the entire period, the growth in real human capital lagged growth in physical assets, which grew at an annual rate of 3.1 percent over the 1994 to

2001 period, of 2.6 percent over the 2001 to 2006 period, and of 2.9 percent over the entire 1994 to 2006 period. [5]

Growth in the human capital stock is very similar to growth in a simple headcount of the U.S. population, which also grew at a rate of 1.1 percent over the 1994 to 2006 period. This implies that virtually all growth in the human capital stock is a result of changes in the size of the U.S. population rather than in the distribution of the U.S. population by age, sex, and education.

Net Investment in the Human Capital Stock

Figures 3a, 3b, and 3c present measures of net investment in the U.S. human capital stock. Net investment in the human capital stock was $6.4 trillion in 2006, of which $1.6 trillion was investment in market human capital and $4.9 trillion was investment in non-market human capital. By comparison, net investment in the physical capital stock equaled $1.2 trillion in 2006.[6] The non-market percentage of net human capital investment shows some volatility, ranging from 72 percent to 78 percent over the 1994 to 2006 period. The general trend over time is toward a greater non-market proportion of investment; a simple regression of percent non-market on time implies that the percent non-market increases by 0.4 percentage points each year.

The most important components of overall net human capital investment are investment from births and depreciation from aging of the non-enrolled; in 2006, births added $9.7 trillion to the human capital stock, while aging subtracted $9.5 trillion from the human capital stock. Net investment from education is the next most important

[5] Author's calculation from Table 1.2 of the Bureau of Economic Analysis's Fixed Assets tables.
[6] Author's calculation from Tables 1.3 and 1.5 of the Bureau of Economic Analysis's Fixed Assets tables; net investment of the physical capital stock is measured as investment in fixed assets and consumer durable goods minus depreciation in fixed assets and consumer durable goods.

component, adding $6.7 trillion to the human capital stock; recall that this not only includes the effects of education itself, but also the effect of the aging of persons while enrolled in school. Deaths had a relatively small impact, subtracting $2.7 trillion from the human capital stock, as did migration, which added $2.0 trillion to the human capital stock. The volatility in net investment from migration is an artifact of its being a residual after births, deaths, aging, and education are accounted for; it is likely a result of measurement error rather than any real volatility. The relative importance of these components of net human capital investment remained roughly the same over the 1994 to 2006 period.

The importance of the different components of human capital differs substantively between net investment in the market component of human capital and net investment in the non-market component of human capital. Aging of the non-enrolled is the largest contributor to (or, in this case, detractor from) the market component of human capital investment. Deaths are virtually irrelevant, since most people die well past their prime earning years. In contrast, the largest contributor to the non-market component of human capital is births.

Figures 4a, 4b, and 4c present measures of net investment in the U.S. human capital stock in real terms. These measures are derived from cost-weighted Fisher indexes that use shifts in population as quantities and per capita human capital as costs by year, age, sex, and education. The general trend in real net human capital investment over time is primarily negative, although this appears to be primarily the result of the unexplained component attributed to migration.

Gross and Net Investment in Education

The greatest shortcoming of this human capital account is the measurement of the contribution of education to human capital as net investment that includes the effects of the aging of the enrolled rather than gross investment that excludes the effects of aging. As mentioned above, the account does not present measures of gross investment because of its sensitivity to assumptions about how persons who did enroll in school would have behaved in future years had they not enrolled in school. Gross investment in education in a given year is equal to the effect of school enrollment on the stock of human capital: the difference between actual human capital and what the stock of human capital would be had no one enrolled in school that year. The latter depends substantially on what assumptions are made about the school enrollment decisions that people who actually did enroll in school would have made in future years had they not enrolled in school.

To illustrate this sensitivity, consider two different scenarios. The first scenario is similar to that of traditional human capital accounts. In this scenario, it is assumed that people who enrolled in school in real life would, in the counterfactual case of no enrollment for one year, become like people who did not enroll in school in real life. This has dramatic implications. Most persons who are enrolled in school are making normal progress in school enrollment with age, and are "on track" to earn their high school diplomas at around age 18 or their bachelor's degrees at around age 22. People who are behind normal progress by a year or two are in a sense "off track", which has serious implications for eventual educational attainment. For example, in 1994, the probability that an "on track" seventeen-year-old male with an eleventh-grade education enrolls in twelfth grade and finishes high school is 94 percent. If he misses a year of education and falls "off track" by one year, that probability drops to 79 percent; fall another year "off track", and it drops further to 30 percent. If we assume that persons who are "on track" would behave like persons who fall "off track" if they missed a year of education, the cost of missing a year of education is very large. Consequently, gross investment in education is extremely high.

In contrast, consider an alternative scenario. In this scenario, we assume that people who attended school in real life would, in the counterfactual of no enrollment for one year, simply pick up where they left off and follow the enrollment pattern they actually followed, except one year later and one year older. In this scenario, people who were enrolled in school would stay "on track" toward finishing their diplomas and degrees in the counterfactual, and would just earn everything they actually did earn one year later. In this scenario, the cost of missing a year of education is much smaller--the only impact is a delay--and so gross investment in education is much smaller.

Figure 5 plots two series of the market component of gross investment in education--under the two counterfactual assumptions described above--plus the series of net investment in education used in the accounts. Under the assumption that persons who did enroll in school would have fallen "off track" had they not enrolled, the market component of gross investment in education in 2006 equals $16 trillion, greater than the entire gross domestic product of the United States. In contrast, under the assumption that persons who did enroll in school would have stayed "on track" with a year's delay, the market component of gross investment in education in 2006 equals $3.1 trillion. This is approximately the same as the market component of net investment in education in 2006, although this is a coincidence.[7] Under this assumption, the market component of gross investment in education is still three and a half times greater than the measured output of education in traditional GDP accounts, which was $852 billion in 2006.[8] Substituting this measure of gross investment in education into GDP as a measure of the output of the education sector would increase total GDP by 17 percent (from $13.2 trillion to $15.4 trillion) and the share of education output in GDP from 6 percent to 20 percent--quite an impact for what is probably a conservative measure of human capital investment from education.

A sensible next step in trying to resolve the sensitivity of gross investment in education to underlying assumptions is to see if changing the construction of the analysis data set reduces this sensitivity. The analysis data set used here assumes that hourly earnings in adulthood only differ across five broad education categories: no high school diploma, high school diploma, some college, college degree, and advanced degree. This is a useful simplification for the purposes of constructing the data set, since it makes it possible to construct estimates of human capital without imputing the distribution of earnings or of the post-school-age population by individual year of education. Unfortunately, it may also contribute to the sensitivity of gross investment to assumptions about the future enrollment choices of the enrolled had they not enrolled. Since the big payoff in earnings comes when one earns a degree, assumptions about whether people would stay "on track" to or fall "off track" from earning their degrees are extremely

[7] The non-market component of gross investment in education is $16.6 trillion under the "off-track" assumption and $2.9 trillion under the "on-track" assumption in 2006; net investment is $3.8 trillion. Net investment is greater than gross investment under the "on-track" assumption because many younger persons actually appreciate as they age and come closer to the greater incomes of adulthood.

[8] Author's calculation from Tables 2.4.5 and 3.17 of the National Income and Product Accounts of the Bureau of Economic Analysis; calculated as the sum of personal consumption expenditures on education and research ($241 billion) and government consumption expenditures on education ($611 billion).

important. The simplification is also a serious stylizing of the actual relationship between education and earnings. Most of the literature on the returns to education finds that although there are discontinuous jumps in earnings when diplomas and degrees are earned, there is also a substantial component of earnings that increases with each year of education; see Jaeger and Page (1996) and Flores-Lagunes and Light (2004) for examples.

A version of the analysis data set that takes into account incremental increases in earnings with increases in the level of education by individual year may yield estimates of investment in education that are less sensitive to counterfactual assumptions. This is because each year of education has its own return, so the cost of falling short of a degree is considerably less. Constructing such a data set is a considerably larger task, since it requires assumptions about the distribution of the population and of earnings by individual year of education for persons of all ages. One approach worth considering for estimating the distribution of earnings by age and years of education is with an earnings regression, although getting the specification of this regression correct would be essential.

Conclusions

Like predecessor studies, this study finds that the size of the human capital stock in the United States is gigantic. When both market and non-market components of human output are combined, the stock of human capital was about three-quarters of a quadrillion dollars in 2006. About 70 percent of this stock is the non-market component. Net investment in human capital, which is primarily the effects of births, aging, and education, was about $6 trillion in 2006; the non-market share of investment is normally between about 70 and 80 percent.

The human capital account produced is not entirely satisfactory, since it does not produce conclusive measures of gross investment in education. The measures of gross investment in education are inconclusive because they are sensitive to counterfactual assumptions about what the future enrollment patterns of persons who are enrolled in school would have been were they not enrolled. Although the absence of conclusive measures of investment in education is disappointing, two interesting results come out of the analysis. First, it is useful to know that measures of gross investment in education can be very sensitive to the assumptions of the human capital account. In particular, the interplay between assumptions about how school enrollment affects future choices and assumptions about the relationship between education and earnings ought to be thought through carefully. Second, even the more conservative estimates of the market component of gross investment in education are more than three times larger than the cost-based measures of educational output in the gross domestic product accounts.

References

Flores-Lagunes, Alfonso, and Audrey Light (2004), "Identifying Sheepskin Effects in the Return to Education," mimeo., April 2004.

Fraumeni, Barbara (2000), "The Output of the Education Sector as Determined by Education's Effect on Lifetime Income," Workshop on Measuring the Output of the Education Sector, The Brookings Institution, April 2000.

Jaeger, David (1997), "Reconciling the Old and New Census Bureau Education Questions: Recommendations for Researchers," *Journal of Business and Economic Statistics* 15(3), pp. 300-309.

Jaeger, David, and Marianne Page (1996), "Degrees Matter: New Evidence on Sheepskin

Effects in the Returns to Education," *Review of Economics and Statistics* 78(4), pp. 733-740.

Jorgenson, Dale, and Barbara Fraumeni (1989), "The Accumulation of Human and Nonhuman Capital, 1948-84," in Robert Lipsey and Helen Stone Tice, eds., *The Measurement of Saving, Investment, and Wealth* (Chicago: University of Chicago Press).

Jorgenson, Dale, and Barbara Fraumeni (1992), "The Output of the Education Sector," in Zvi Griliches, ed., *Output Measurement in the Service Sectors* (Chicago: University of Chicago Press).

Appendix: Details on the Imputation of the Distribution of the Population by Individual Year of Education

The first step taken in estimating the population of persons age 34 and younger by age, sex, and individual year of education is to create a new educational attainment variable in the October CPS. This variable places persons into broad educational categories that are likely to crosswalk to individual years of education. It combines the post-revision educational attainment variable from the basic CPS and the grade enrolled variable from the October school enrollment supplement. This variable, henceforth referred to as categorical education, was created as below:

IF ENROLLED IN SCHOOL IN	IF NOT ENROLLED AND CPS ATTAINMENT IS	CATEGORICAL YEARS OF EDUCATION IS
1st grade	None or less than 1st grade	Zero
2nd, 3rd, 4th, or 5th grade	1st, 2nd, 3rd, or 4th grade	One to four
6th or 7th grade	5th or 6th grade	Five to six
8th or 9th grade	7th or 8th grade	Seven to eight
10th grade	9th grade	Nine
11th grade	10th grade	Ten
12th grade	11th grade 12th grade no diploma	Eleven
1st year college	High school graduate	Twelve
2nd, 3rd, or 4th year college	Some college Associate's (occupational) Associate's (academic)	Thirteen to fifteen
5th year college 6th year college or more*	Bachelor's degree	Sixteen to seventeen
6th year college or more*	Master's degree Professional degree Doctoral degree	Eighteen or more

*Students in their 6th year of college or more are put into the "sixteen or seventeen" category if their CPS attainment is bachelor's degree, "eighteen or more" category otherwise.

After creating this new categorical education variable, the October CPS can be used to generate estimates of the U.S. civilian population age 34 and younger by age, sex, categorical education, and school enrollment for each year. These estimates can be used to create estimates of the U.S. civilian population age 34 and younger by age, sex, and individual year of education given assumptions about the distribution of persons by individual years of education within groups defined by age, sex, categorical education, and school enrollment. The approaches used to create those assumptions are described in the table below.

Population	Method of imputing distribution of individual years of education by age and sex
Persons between ages 0 and 17 who are enrolled in school.	Completed education assumed to be grade enrolled minus one.
Persons between ages 0 to 6 who are not enrolled in school.	All assumed to have zero years of education.
Persons between ages 7 and 14 who are not enrolled in school	Distribution of individual years of education assumed to be equal to distribution among persons enrolled in school of the same sex and age.
Persons between ages 15 and 17 who are not enrolled in school	Distribution of individual years of education assumed to be equal to distribution among persons enrolled in school of the same sex, age, and categorical education.
Persons between ages 18 and 34 whose categorical education is zero years	All assumed to have zero years of education.
Persons between ages 18 and 34 who are enrolled in school and whose categorical education is one to four years, five to six years, or seven to eight years.	Completed education assumed to be grade enrolled minus one.
Persons between ages 18 and 34 who are not enrolled in school and whose categorical education is one to four years, five to six years, or seven to eight years.	Distribution of individual years of education assumed to be equal to distribution among persons enrolled in school of the same sex, age, and categorical education.
Persons between ages 18 and 34 whose categorical education is nine, ten, eleven, or twelve years.	All assumed to have (respectively) nine, ten, eleven, or twelve years of education.
Persons between ages 18 and 34 whose categorical education is thirteen to fifteen years.	Distribution of individual years of education is initially imputed from historical enrollments in 13th through 16th years of education, as shown above. Shares of persons by individual year of education are bounded at the bottom by zero. The results are smoothed three times. First, the shares are smoothed over age within years, using a quadratic trend in age

	that only applies after age 21. Second, the school enrollment rates implied by the smoothed shares and by enrollment counts computed from the October CPS are calculated. The school enrollment rates are smoothed from year to year by age and sex using a three-year moving average. The smoothed enrollment rates are capped at 95 percent. New shares of persons by individual year of education are computed using the smoothed enrollment rates and enrollment counts by year of education. Third, the shares computed from the second smoothing are smoothed from year to year by age and sex using a three-year moving average. These shares are adjusted if the enrollment rate following this adjustment exceeds 95 percent.
Persons between ages 18 and 34 whose categorical education is sixteen to seventeen years.	Distribution of individual years of education is initially imputed from historical enrollments in 16th through 18th years of education, in a way like that shown above. Enrollments among persons who have already completed a graduate degree are ignored, since they will have enrolled in the "18th" year of education multiple times. The results are smoothed three times. First, the shares are smoothed over age within years using a moving average across three consecutive ages. The share of persons with 17 years of education is bounded at the bottom at 3 percent. Second, the school enrollment rates implied by the smoothed shares and by enrollment counts computed from the October CPS are calculated. The school enrollment rates are smoothed from year to year by age and sex using a three-year moving average. The smoothed enrollment rate in the 17th year of education is bounded to be between zero and one hundred percent; the smoothed enrollment rate in the 18th year of education is bounded to be between zero and eighty percent. New shares of persons by individual year of education are computed using the smoothed enrollment rates and enrollment counts by year of education. Third, the shares computed from the second smoothing are smoothed from year to year by age and sex using a three-year moving average. These shares are adjusted if enrollment rates following this adjustment violate the bounds set above.
Persons between ages 18 and 34 whose categorical education is eighteen years or more.	Completed education is assumed to be eighteen years.

Figure 1. Human capital stock (in trillions)

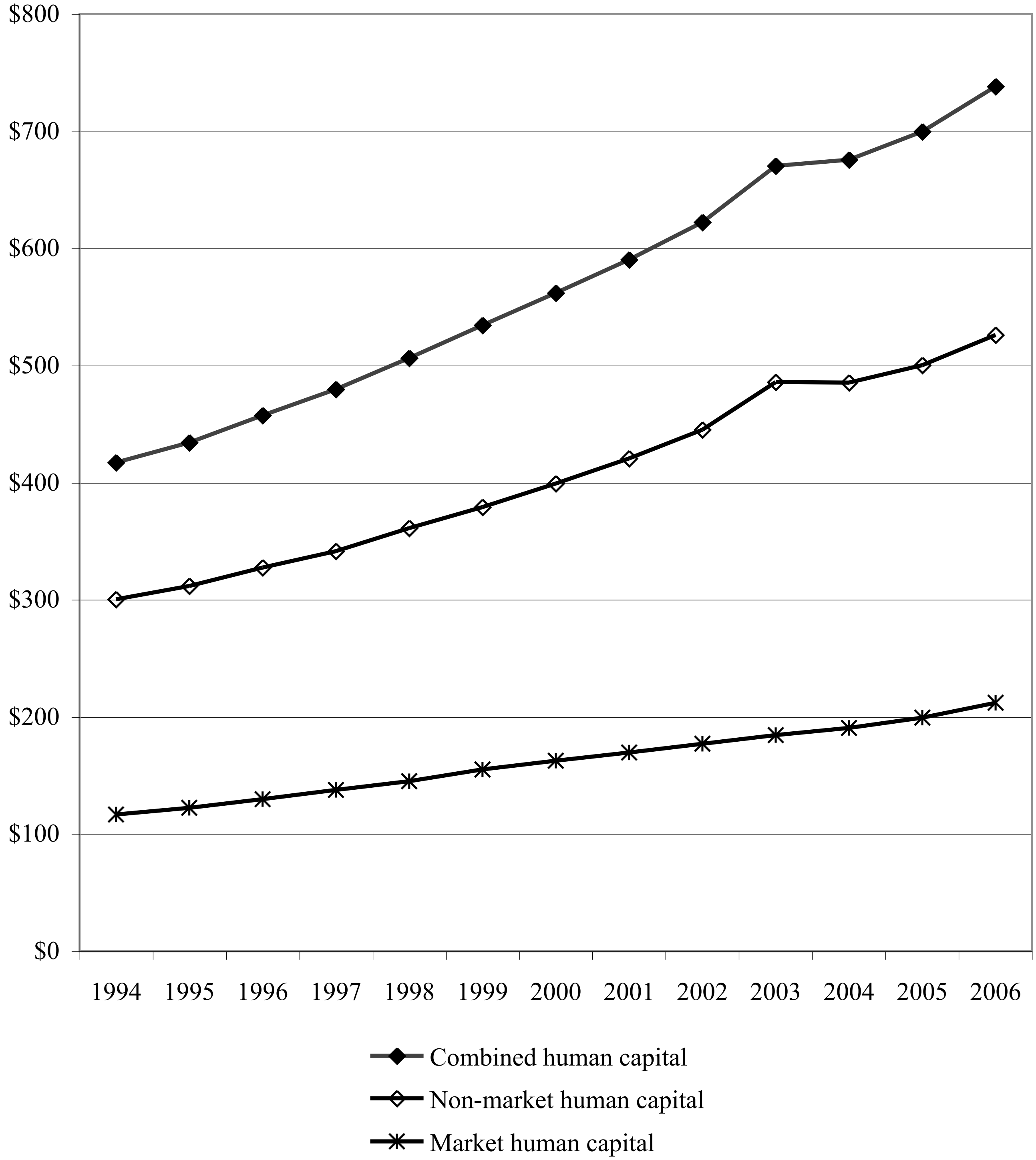

Figure 2. Real human capital stock
(in trillions of 2006 dollars)

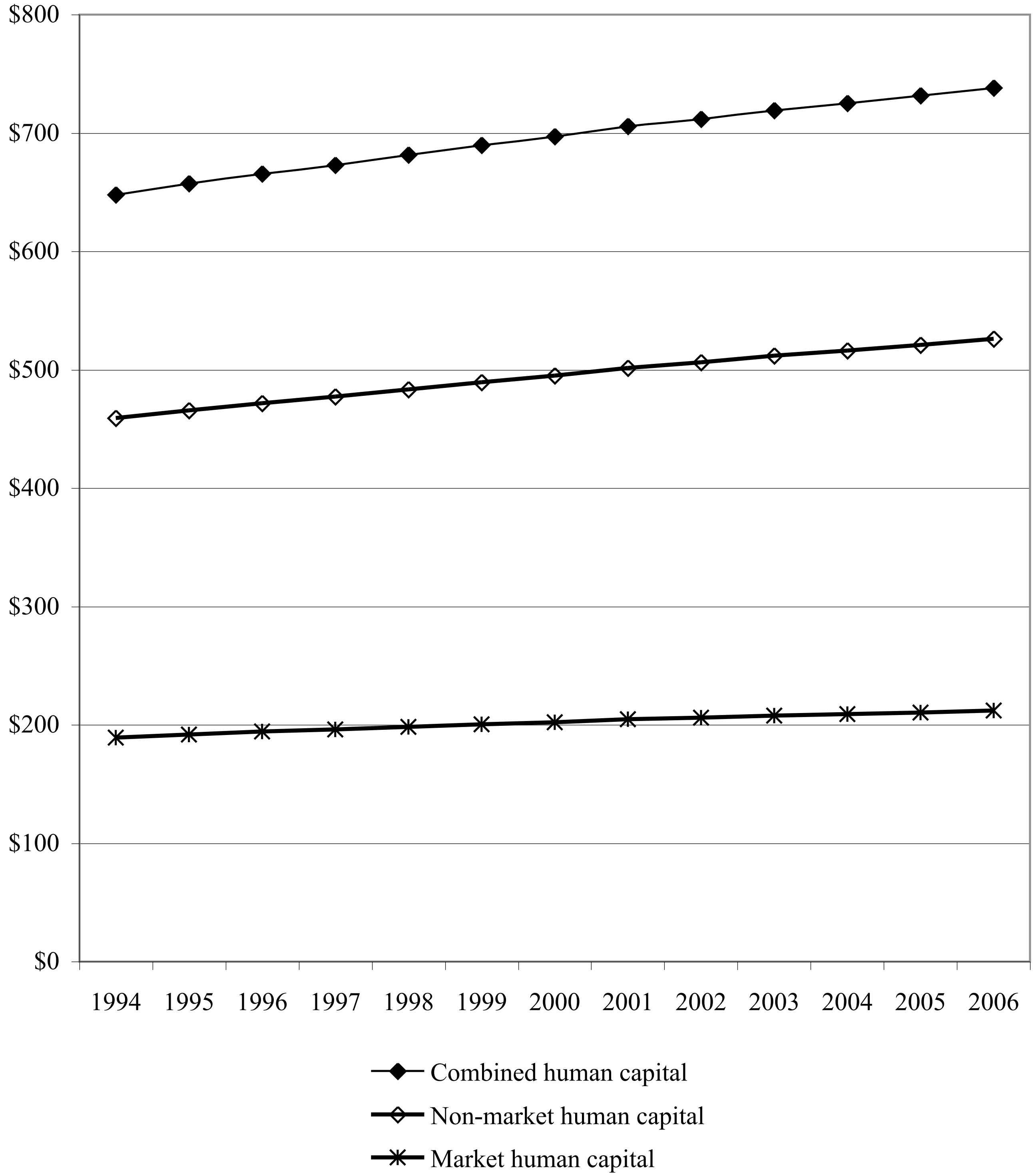

**Figure 3a. Net investment in human capital
(in trillions)**

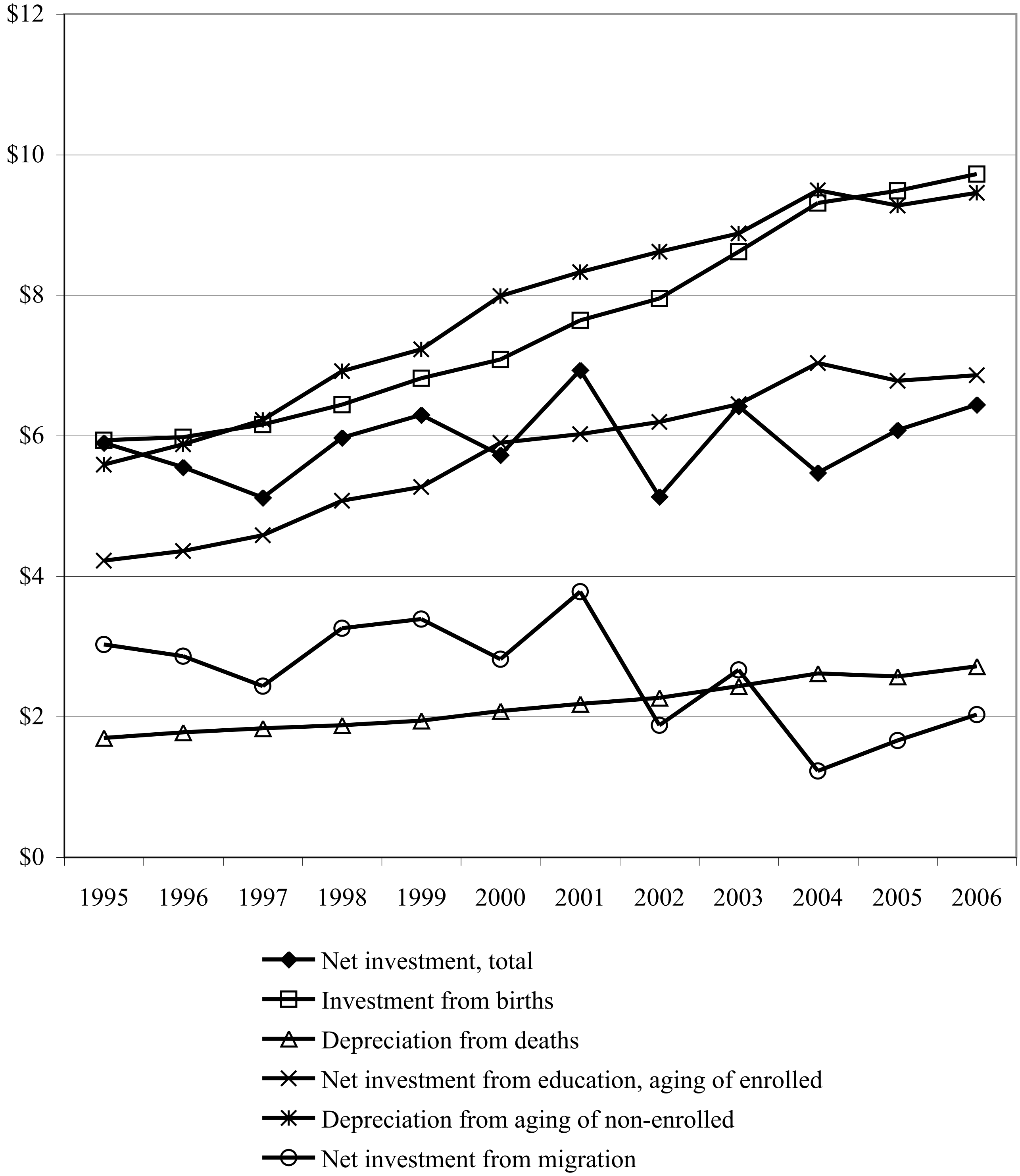

Figure 3b. Net investment in market human capital (in trillions)

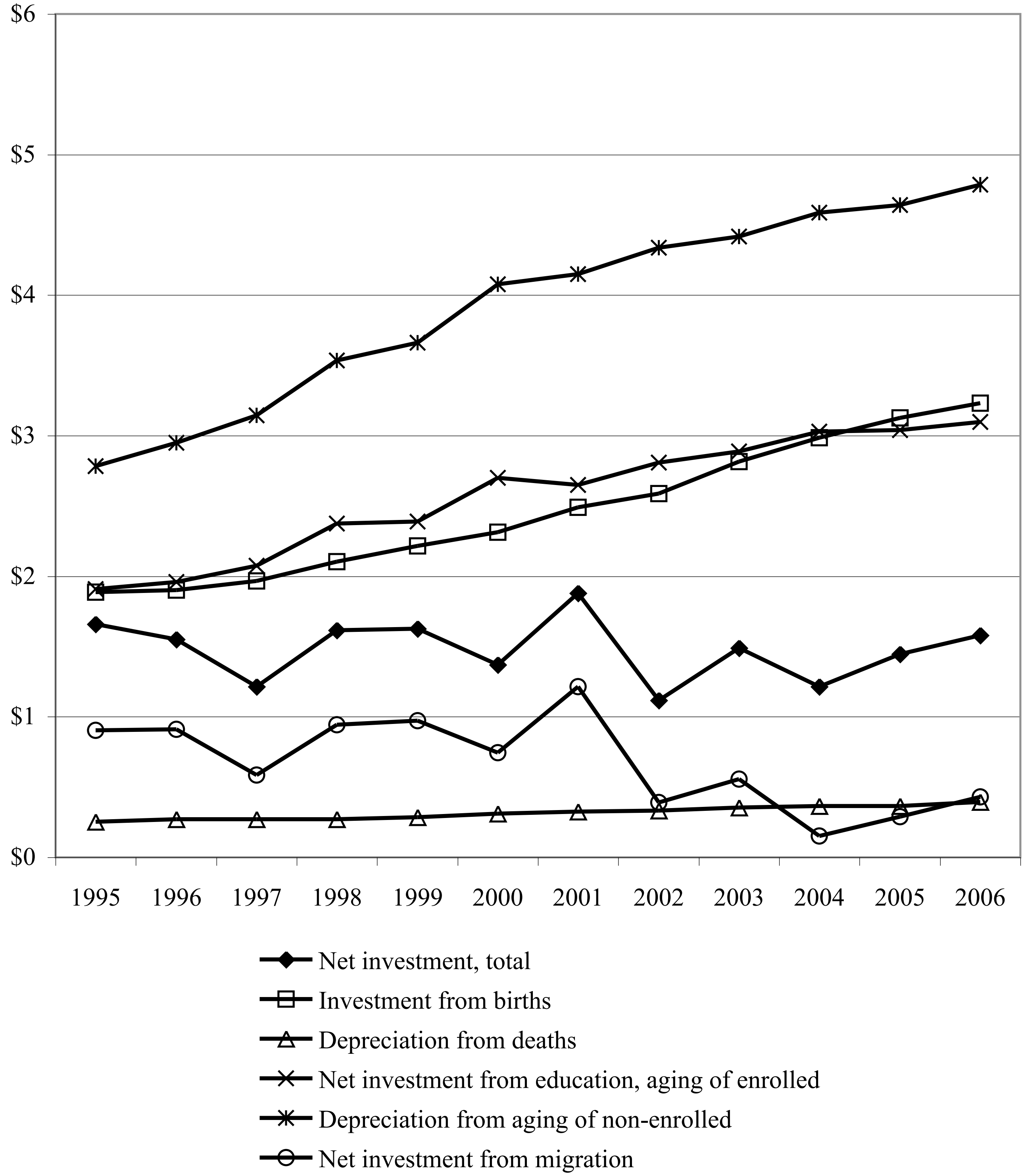

Figure 3c. Net investment in non-market human capital (in trillions)

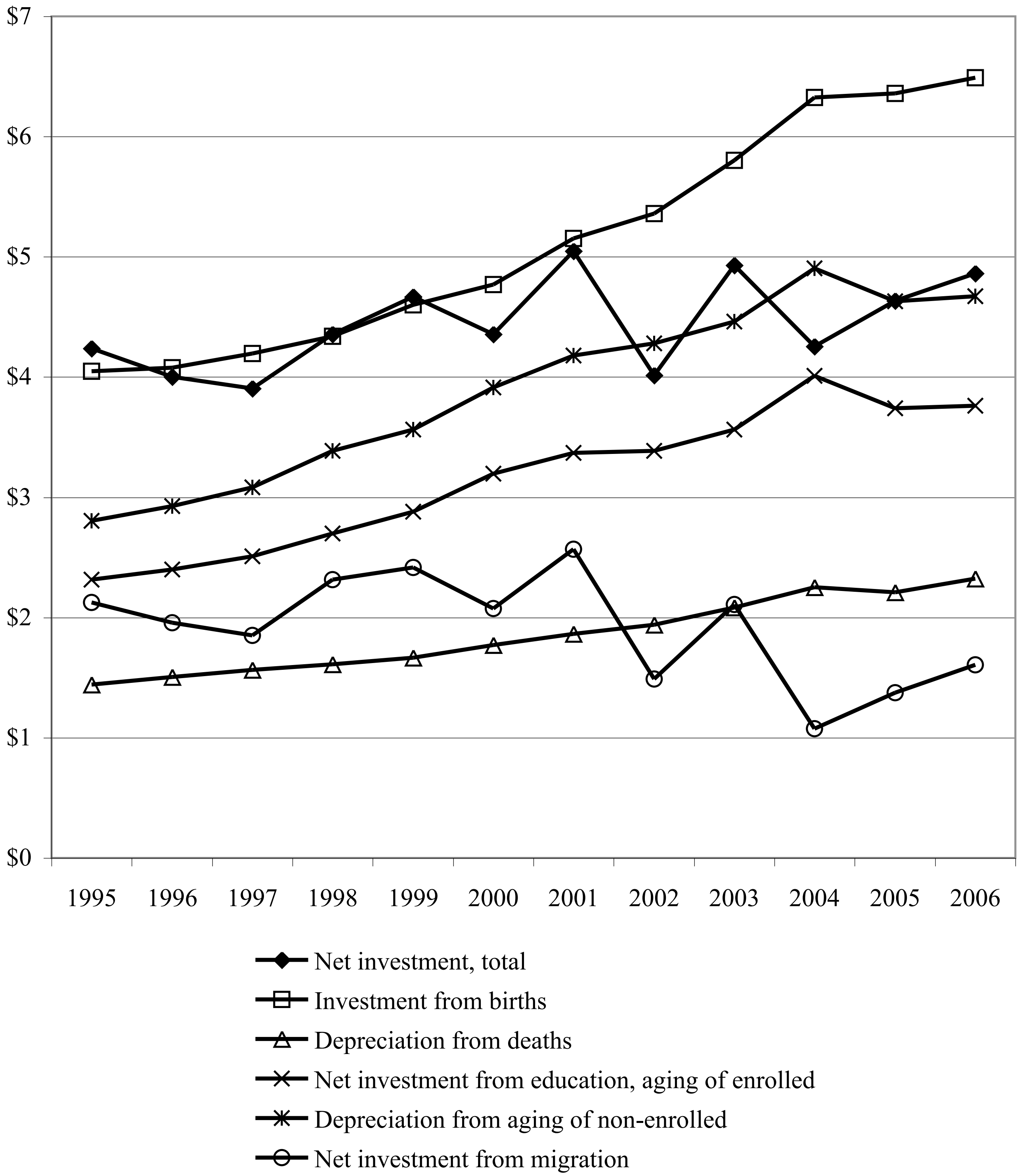

Figure 4a. Real net investment in human capital
(in trillions of 2006 dollars)

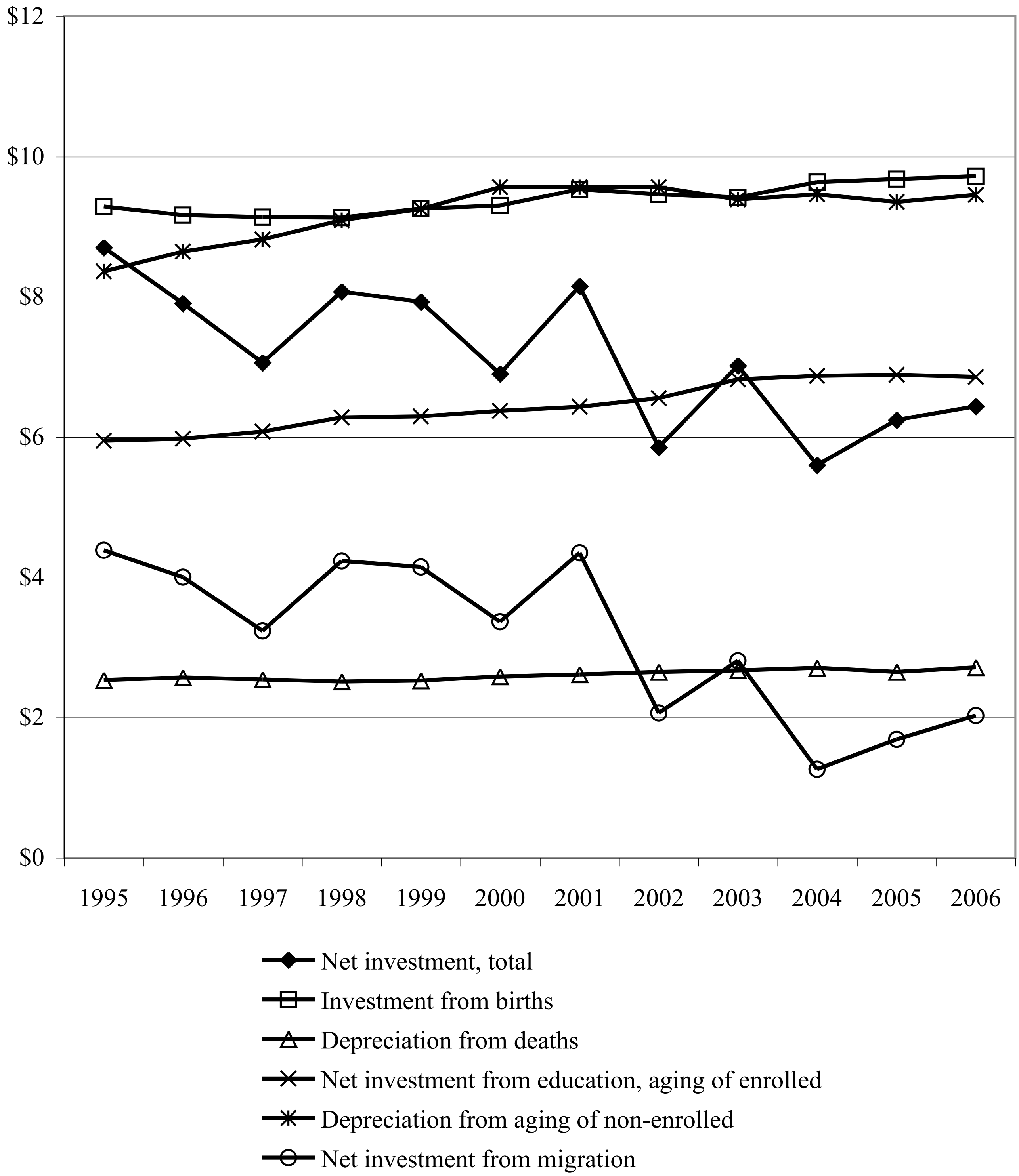

Figure 4b. Real net investment in market human capital (in trillions of 2006 dollars)

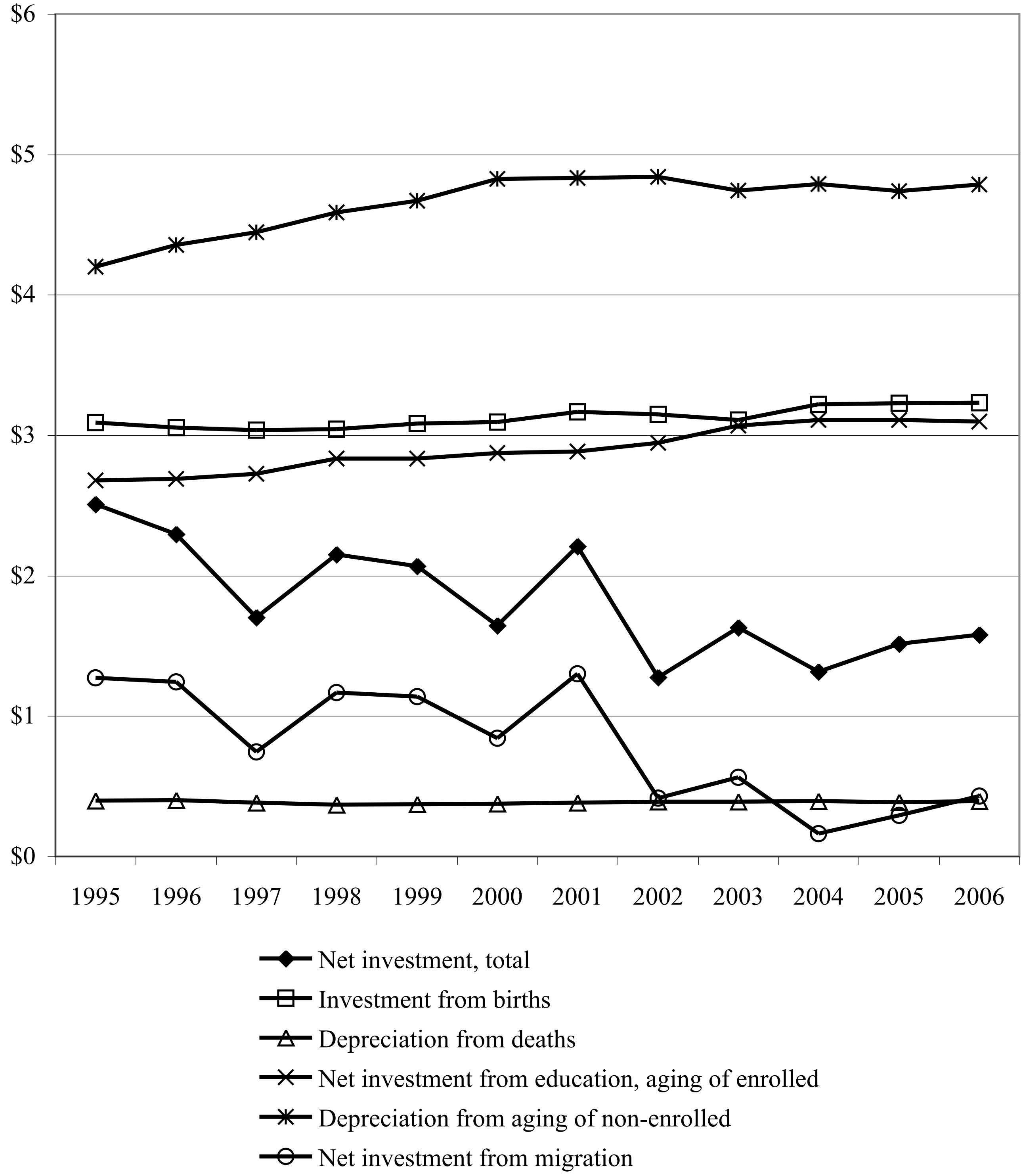

Figure 4c. Real net investment in non-market human capital (in trillions of 2006 dollars)

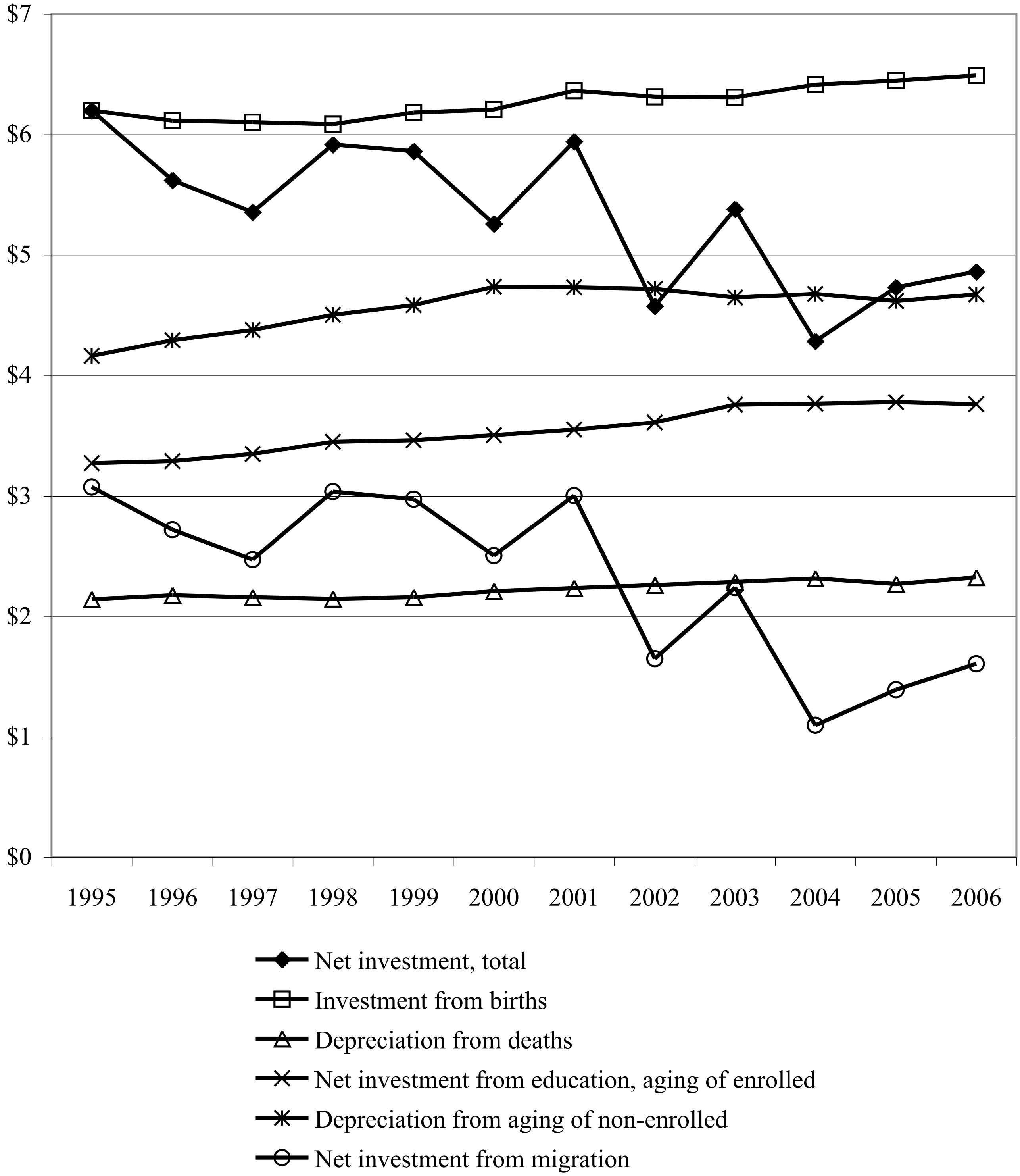

Figure 5. Market component of investment in human capital