The Value and Risk of Human Capital

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Abstract

Human capital embodies the knowledge, skills, health, and values that contribute to making people productive. These qualities, however, are hard to measure, and quantitative studies of human capital are typically based on the valuation of the lifetime income that a person generates in the labor market. This article surveys the theoretical and empirical literature that models a worker's life-cycle earnings and identifies appropriate discount rates to translate those cash flows into a certainty equivalent of wealth. We begin with an overview of a stylized model of human capital valuation with exogenous labor income. We then discuss extensions to this framework that study the underlying economic sources of labor income shocks, the choices that people make during their lives (such as about work, leisure, retirement, and investment in education), and the implications of these factors for human capital valuation and risk.

1. INTRODUCTION

We think of human capital broadly as the set of knowledge, skills, health, and values that contribute to making people productive (e.g., Becker 1964). In a free society, any contract written against future labor services is not strictly enforceable, and ownership of human capital is restricted to the person who embodies it, i.e., labor income is a nontraded asset. Hence, quantitative analyses of human capital are typically based on the valuation of the income flow that a person generates by renting services in the labor market. Although intuitive, this definition is hardly operational without sufficient knowledge of the worker's life-cycle earnings and of appropriate discount rates to translate those cash flows into a certainty equivalent of wealth.

Modeling a worker's lifetime earnings is challenging. Heterogeneity in ability and in preference for leisure results in cross-sectional income dispersion. Moreover, people adjust their labor supply and the amount of effort they exert at work to buffer wealth, health, and labor income shocks. Further, workers can choose their retirement date to optimally smooth consumption. Finally, career choices and human capital investment in the form of education have a significant impact on lifetime earnings. Owing to the complexity of a structural model of labor income that accommodates all these features, researchers often focus on a reduced-form specification to estimate the distribution of lifetime earnings. They then rely on this statistical model to determine labor income flows in the valuation of human capital.

Identifying a discount rate for the valuation of human capital also presents a challenge. The appropriate rate should reflect the riskiness of workers' labor income flows, which are subject to unexpected fluctuations. Some of these fluctuations are linked to changes in general economic conditions. For instance, wages and employment rates are typically lower when the economy does poorly, especially during a long recession. Similarly, some health problems could increase in the population during an extended economic downturn and contribute to lower aggregate earnings.[1] However, labor income also contains a significant idiosyncratic component. For example, many health shocks that are unrelated to aggregate economic conditions could force a person out of the labor force. Similarly, individual productivity shocks could affect a worker's earnings regardless of the overall state of the economy.

In a perfect market, workers could fully insure earnings against shocks by trading explicit claims written against future labor income flows. In practice, market imperfections such as moral hazard, adverse selection, transaction costs, and legal restrictions preclude trading such claims. Self-insurance via precautionary savings and government-sponsored programs (e.g., unemployment insurance and Medicaid in the United States) helps workers to smooth consumption. Moreover, traded assets like stocks, bonds, and real estate fluctuate with general economic conditions and therefore provide a partial hedge against labor income shocks. However, workers remain exposed to idiosyncratic shocks that are not spanned by traded assets. Because such shocks cannot be hedged, the appropriate rate at which to discount future earnings depends on workers' preferences.

In this article, we discuss how the recent literature tackles these issues. We begin with a stylized life-cycle model of consumption-saving decisions in which labor income is exogenous. Section 2 lays out a widely used statistical model that explains life-cycle earnings in terms of three main components: a deterministic function of individual characteristics, persistent shocks, and transient shocks. We then review the studies that explore the empirical properties of these three components. Next, we derive a rate at which a utility-maximizing worker discounts future earnings

[1] *The Economist* (2013) provides a nontechnical overview of the literature that studies the linkage between economic downturns and health outcomes.

flows to determine the value of human capital. The section ends with a synthesis of the financial economics literature that uses this setup to study the value and risk of human capital.

Section 3 extends the framework along several dimensions. First, we review literature that explicitly models work/leisure and retirement decisions rather than treating labor income as an exogenous process. Second, we discuss human capital investment in the form of schooling, training, and early childhood education. We review theory and evidence with an emphasis on the role of education and credit constraints in explaining heterogeneity in earnings and therefore in human capital valuation. Third, we explore various sources of risk that underlie persistent and transient earnings shocks. Examples of such risks include shocks to individual productivity, health shocks, job arrival shocks, and firm-level shocks that may lead to job creation or destruction. Fourth, we provide an analysis of the linkage between labor income shocks and aggregate economic fluctuations and discuss the implications of time-varying correlations between earnings and stock returns for the value and risk of human capital. Finally, Section 4 concludes this article with summary points and suggestions for future work.

2. A MODEL OF HUMAN CAPITAL VALUATION

Valuing human capital involves the pricing of nontradable future cash flows that a worker will earn in the labor market. Such an exercise requires two basic ingredients: a model for the worker's earnings over the life cycle and an appropriate rate at which to discount those cash flows. Section 2.1 outlines a standard model for the worker's labor income and surveys the studies that provide empirical support for it. Section 2.2 presents a stylized life-cycle model of consumption and savings decisions that determines a discount rate for human capital valuation. In Section 2.3, we provide an overview of the financial economics literature that combines these two ingredients to study the value of human capital.

2.1. A Statistical Model of Labor Income

For simplicity, here we follow much of the literature in assuming that the labor income process is exogenous. That is, we ignore workers' ability to adjust their labor supply, to optimally choose a retirement date, and to invest in their human capital by pursuing more years of education. Although these considerations are important, the assumption that labor income is exogenous is a reasonable starting point as long as the earnings profiles of the model used for human capital valuation closely match the outcomes of workers' decisions reflected in labor income data. We will return to these issues in the second part of the article.

The labor income model of MaCurdy (1982) and Abowd & Card (1989) has become a standard tool in the literature on life-cycle consumption and investment decisions (e.g., Carroll & Samwick 1997; Campbell et al. 2001; Gourinchas & Parker 2002; Cocco, Gomes & Maenhout 2005; Brown, Fang & Gomes 2012). It assumes that a worker i's age-t labor income, $Y_{i,t}$, is the sum of deterministic and stochastic components,

$$\log(Y_{i,t}) = f(t, Z_{i,t}) + \nu_{i,t} + \varepsilon_{i,t}, \quad t \leq K, \tag{1}$$

where K is the last year before worker i retires.

The first term, $f(t, Z_{i,t})$, is a deterministic function of age t and other individual characteristics $Z_{i,t}$. Empirical evidence suggests that a third-order polynomial in age provides a good fit for age effects (e.g., Cocco, Gomes & Maenhout 2005; Brown, Fang & Gomes 2012). Estimation on household-level or individual labor income data delivers a hump-shaped life-cycle earnings profile, consistent with stylized facts on income dynamics (e.g., Attanasio 1995; Hubbard, Skinner

& Zeldes 1995; Gourinchas & Parker 2002). Other individual characteristics $Z_{i,t}$ help to explain the life-cycle profile of earnings. For instance, higher levels of education are typically associated with higher lifetime earnings. Other covariates considered in the literature are gender, marital status, household size, and other demographic variables (e.g., Hubbard, Skinner & Zeldes 1995; Cocco, Gomes & Maenhout 2005; Guvenen 2009; Brown, Fang & Gomes 2012).

The next two terms in Equation 1 capture idiosyncratic shocks. The labor income literature distinguishes between persistent shocks, denoted here by $\nu_{i,t}$, and transient shocks $\varepsilon_{i,t}$. It is common to posit that $\nu_{i,t}$ follows a first-order autoregressive process,

$$\nu_{i,t} = \phi\, \nu_{i,t-1} + u_{i,t}, \tag{2}$$

where $u_{i,t}$ is a Gaussian independently and identically distributed (i.i.d.) mean-zero error uncorrelated across households with constant variance σ_u^2. As for the transient shocks, the literature assumes that the $\varepsilon_{i,t}$ process is uncorrelated across households and independent over time with identical Gaussian distribution and constant variance σ_ε^2.

Much effort has gone into determining the persistence of the $\nu_{i,t}$ process. Early work estimated $\nu_{i,t}$ to have only modest persistence and attributed most of the observed cross-sectional variation in earnings to heterogeneity in the deterministic component of labor income profiles (e.g., Lillard & Weiss 1979, Hause 1980). More recently, several studies have revisited this question and have estimated the autoregressive coefficient ϕ to be close to one (e.g., MaCurdy 1982; Abowd & Card 1989; Hubbard, Skinner & Zeldes 1995; Storesletten, Telmer & Yaron 2004; Guvenen 2009). This evidence has motivated several authors to assume that the $\nu_{i,t}$ shocks are permanent. For instance, that $\nu_{i,t}$ follows a random walk, $\phi = 1$, is assumed by Carrol (1997); Carroll & Samwick (1997); Campbell et al. (2001); Gourinchas & Parker (2002); Haliassos & Michaelides (2003); Cocco, Gomes & Maenhout (2005); and Brown, Fang & Gomes (2012).

Carroll & Samwick (1997) develop a method for decomposing innovations into transitory and permanent components. Using Panel Study of Income Dynamics (PSID) data from 1981 to 1987, they estimate the variance σ_ε^2 of the transient component to be approximately twice as large as the variance of the permanent shocks σ_u^2. They go on to document wide heterogeneity in their estimates across workers' characteristics, such as education, occupation, and age. For instance, they find an inverse-U pattern in permanent shocks as a function of education: Their σ_u^2 estimates increase until workers reach a high school diploma, and they progressively decline for workers who have a higher level of education. In contrast, they find a U-shaped pattern in transitory shocks σ_ε^2 as a function of education. Further, they show a mild U-shaped pattern of both σ_u^2 and σ_ε^2 in age.

Several studies after Carroll & Samwick (1997) have followed a similar approach to investigate the properties of labor income risk. Differences in data sources, sample periods, labor income measures, and model specification make it difficult to directly compare their findings. This might explain why the conclusions of this body of research are often conflicting. For example, Hubbard, Skinner & Zeldes (1995) estimate lower σ_u^2 and σ_ε^2 coefficients for more educated workers. Campbell et al. (2001) document an increasing pattern in permanent shocks as a function of education and a decreasing relation for transitory shocks. Finally, Meghir & Pistaferri (2004) and Brown, Fang & Gomes (2012) show a U-shaped pattern for permanent shocks, whereas transitory shocks are decreasing in education.

In this model, workers retire at a fixed age K. From that moment, they receive retirement income, which may come in different forms. In the United States, Social Security is the primary source of retirement income for the majority of retirees; benefits are calculated based on a worker's average indexed monthly earnings during the 35 years of highest earnings. Although defined-benefit pension plans are becoming less common, there is still a significant portion of the US population that is entitled to such benefits through their former employer; in this case, benefits are typically computed as a fraction of income earned during the last few years prior to retirement. Alternative pension plans [e.g., defined-contribution 401(k) and thrift plans] are also funded by workers by setting aside a fraction of their annual income. Hence, it is reasonable to model retirement income as a constant fraction $\lambda(Z_{i,K})$ of permanent labor income in the last working year K, where $\lambda(Z_{i,K})$ is a function of individual characteristics $Z_{i,K}$:

$$\log(Y_{i,t}) = \log(\lambda(Z_{i,K})) + f(t, Z_{i,K}) + \nu_{i,K}, \quad t > K. \tag{3}$$

Among others, Cocco, Gomes & Maenhout (2005) and Brown, Fang & Gomes (2012) follow this approach in their empirical investigation of life-cycle labor income profiles.

2.2. The Private Versus Market Valuation of Human Capital

We can think of labor income as the cash flow generated by a worker's human capital. Most people rely on their wages to pay for food, shelter, and other necessities. Although human capital is possibly their most valuable asset, market imperfections such as moral hazard, adverse selection, transaction costs, and legal restrictions preclude their borrowing against it by trading explicit claims to their future earnings.

The same market imperfections prevent people from insuring fully against labor income shocks. Self-insurance via precautionary savings and government-sponsored programs (e.g., unemployment insurance and Medicaid in the United States) helps workers to smooth consumption. Moreover, traded assets like stocks, bonds, and real estate provide a partial hedge for labor income shocks. However, workers remain exposed to idiosyncratic shocks that are not spanned by traded assets. Because these shocks cannot be hedged, the discount rate for future labor income flows may differ from the market discount rate.

In general, the implicit value of a nontraded asset is specific to a person and depends on individual preferences. Only when the cash flows from the nontraded asset are spanned by traded assets, i.e., the market is complete, would the value of the nontraded asset be independent of preferences (e.g., He & Pearson 1991; Svensson & Werner 1993).

To illustrate the private valuation of human capital, it is useful to start from the life-cycle consumption/savings problem of a person who does not earn labor income. We then consider the hypothetical scenario in which the person can trade a claim to future labor income flows, and we determine the shadow price at which he or she is willing to hold that claim based on his or her preferences (e.g., Svensson & Werner 1993).

A person i with time-separable utility is endowed with positive initial wealth $W_{i,0}$ and lives for T years. The person begins each year with wealth from the previous year plus accumulated interest, $W_{i,t-1}(1+r)$, where r is a constant rate of return on invested wealth. Each year the person consumes $C_{i,t}$ to maximize the utility function

$$\mathrm{E}_1\left[\sum_{t=1}^{T} \beta^{t-1} U(C_{i,t})\right], \tag{4}$$

where β is an intertemporal discount factor, subject to the budget constraint

$$C_{i,t} = (1+r)\,W_{i,t-1} - W_{i,t}. \tag{5}$$

Further, we assume that the person has no access to borrowing, i.e., for each year t, $W_{i,t} \geq 0$.

Suppose now that the same person is allowed to trade a hypothetical asset that generates the labor income flow $Y_{i,t}$ with dynamics in Equations 1–3. The implicit value of human capital is then the price V_i at which the person would hold that asset if it were traded on the market. Denote by θ the amount of the human capital asset the person chooses to buy subject to the augmented budget constraint

$$\begin{aligned} C_{i,t} &= (1+r)W_{i,t-1} - W_{i,t} + \theta Y_{i,t} - \theta V_i \qquad &\text{for } t=1, \\ C_{i,t} &= (1+r)W_{i,t-1} - W_{i,t} + \theta Y_{i,t} \qquad &\text{for } 1 < t \leq T. \end{aligned} \tag{6}$$

In Equation 6, θV_i denotes the time-1 cost incurred to acquire the human capital asset, and $\theta Y_{i,t}$ denotes the time-t cash flow associated with that claim. The person will then choose θ and consumption flow C_i to maximize intertemporal utility. The first-order condition of the utility function in Equation 4 with respect to θ yields

$$\begin{aligned} 0 &= \mathrm{E}_1\left[\sum_{t=1}^{T} \beta^{t-1}\, U'(C^*_{i,t}) \frac{\partial C^*_{i,t}}{\partial \theta}\right] \\ &= -U'(C^*_{i,1})\, V_i + \mathrm{E}_1\left[\sum_{t=1}^{T} \beta^{t-1}\, U'(C^*_{i,t}) Y_{i,t}\right], \end{aligned} \tag{7}$$

where C^*_i denotes the optimal consumption plan. Equation 7 yields the standard optimality condition, $U'(C^*_{i,1})\, V_i = \mathrm{E}_1[\sum_{t=1}^{T} \beta^{t-1}\, U'(C^*_{i,t}) Y_{i,t}]$, which equates the marginal utility cost of acquiring one additional unit of the human capital asset to the marginal benefit of receiving the associated additional labor income cash flows. Rearranging Equation 7 gives the implicit value of human capital:

$$V_i = \mathrm{E}_1\left[\sum_{t=1}^{T} \beta^{t-1} \frac{U'(C^*_{i,t})}{U'(C^*_{i,1})} Y_{i,t}\right]. \tag{8}$$

2.3. The Value and Risk of Human Capital

The setup of Section 2.2 is abstracted from a number of important issues. First, it assumes that people invest their savings exclusively in a safe asset, although in reality they face an array of investment options, e.g., stocks, bonds, and real estate. Second, the life span is fixed at T years, although in reality people face mortality risk. Third, preferences in this setup exclude a bequest motive.

Cocco, Gomes & Maenhout (2005) consider a more general setting that overcomes these limitations. They explicitly model the problem of the life-cycle portfolio choice of a worker with constant relative risk aversion preferences who splits his or her financial wealth between a risk-free bond and a portfolio of stocks. Along the way, they account for mortality risk as in, e.g., Hubbard, Skinner & Zeldes (1995) and introduce a bequest motive in the worker's utility function. The labor income dynamics are similar to Equations 1–3 with permanent idiosyncratic shocks ($\phi = 1$ in Equation 2) and with coefficients estimated on PSID data. They assume that the worker retires at age 65, and they calibrate survival probabilities using the mortality tables of the National Center for Health Statistics. The relative risk aversion coefficient, intertemporal discount rate, risk-free rate, and equity premium are fixed at values commonly found in the literature.

Cocco, Gomes & Maenhout (2005) solve their model numerically and evaluate the implicit value of human capital by discounting labor income flows at the worker's intertemporal marginal rate of substitution (Equation 8). They find the value of human capital to be hump-shaped over the life cycle with a peak around age 35. That is, although young people face a longer stream of future labor income, they discount such cash flows more than older people. This occurs for two reasons. First, the predictable labor income component has a hump-shaped profile: Cash flows of higher labor income occur at older ages and therefore are subject to greater time discounting. Second, as workers age, they face lower idiosyncratic labor income uncertainty. Consistent with this intuition, Benzoni, Collin-Dufresne & Goldstein (2007) document that a worker's discount rate associated with permanent idiosyncratic labor income shocks has a downward-sloping profile.

Brown, Fang & Gomes (2012) consider a similar setup that abstracts from portfolio choice decisions and focuses instead on the linkage between a worker's education and the value of his or her human capital. The authors consider three levels of education: workers without a high school diploma, those with one, and college graduates. They estimate the labor income model on PSID data from 1968 to 2007 on a sample of PSID heads of household who are still in the labor force and who are aged between 20 (22 if college graduates) and 65. The measure of income includes post-tax labor income, unemployment income, and Social Security benefits. As in Equation 3, workers after retirement receive a constant fraction of permanent labor income in the last working year.

For a range of preference parameters, Brown, Fang & Gomes (2012) find that the typical high school graduate will enjoy a level of consumption that is 24% higher than those who did not attend high school. When expressed in terms of lifetime certainty equivalent (i.e., risk-adjusted) wealth, this corresponds to an increase of $220,000 in 2010 dollars. The gain from college education is larger. The increase in present value of human capital of the average college graduate is $432,000, which corresponds to a 38.5% increase in annual certainty-equivalent consumption. These estimates are smaller than the numbers often found in the popular press; for instance, the US Census Bureau (2011) estimates that a college degree increases lifetime earnings by around one million dollars compared with lifetime earnings of a worker with a high school diploma. Brown et al. attribute the differences to the measure of labor income they use, which is net of income and payroll taxes, and to the risk-adjusted discount rate they apply when valuing income flows from future labor.

Further, differences in risk aversion, unemployment risk, and earnings volatility can produce significant heterogeneity in estimated returns to education. This sets the results of Brown, Fang & Gomes (2012) apart from the labor economics literature that studies the linkage between education and earnings via linear regressions without giving full consideration to risk (e.g., Card 1999). In particular, Brown et al. estimate a U-shaped pattern in permanent labor income shocks as a function of education. They find that high school graduates face lower idiosyncratic risk than workers without a high school diploma and college graduates. Hence, high school graduates discount future earnings at a lower rate, which increases the present value of their human capital. College graduates experience higher expected earnings and lower unemployment risk. However, they also face a much more skewed distribution of lifetime earnings owing to, e.g., career earnings heterogeneity. Thus, they discount future earnings at a higher rate.[2]

3. EXTENSIONS AND DIRECTIONS FOR FUTURE WORK

The discussion so far has focused on statistical models that treat labor income as an exogenous process. Here we discuss the literature that extends the analysis to account for work/leisure and retirement decisions, as well as the choice to invest in human capital in the form of education. Further, the framework of Section 2 is silent about the economic sources of risk that underlie shocks to earnings and, thus, cannot be used to disentangle fluctuations in income owing to

[2]The conclusions of Brown, Fang & Gomes (2012) hinge on their estimate of a U-shaped pattern in the variance of permanent idiosyncratic shocks with respect to education. This pattern, however, is controversial in the literature (see the discussion in Section 2.1). Reaching a consensus on the decomposition of labor income shocks into permanent and transitory components remains an important area of work.

exogenous shocks from fluctuations owing to the effects of actions taken by workers in response to such shocks (e.g., adjusting hours worked or retirement date). To shed light on these issues, we review recent studies that explicitly model shocks to individual productivity, health shocks, job arrival shocks, and firm-level shocks that may lead to job creation or destruction and their role in driving labor income fluctuations. Moreover, we discuss work that explores the link between labor income shocks and aggregate economic fluctuations. Delving more into these issues is important to obtain a more precise estimate of the value of human capital and to better understand the sources of its risk.

3.1. Models of Labor Supply

The labor income model in Section 2.1 specifies a univariate process of earnings. Thus, its ability to identify the various sources of fluctuations in income is limited. In contrast, recent work in labor economics focuses on multivariate models that include the distinct determinants of earnings. For instance, Altonji, Smith & Vidangos (2013) consider specifications that incorporate hours and wages, as well as discrete events such as job changes, employment loss, interactions between job changes and wages, and the effects of these discrete events on the variance of wage and hours shocks.

The framework of Altonji, Smith & Vidangos (2013) is very rich. Although not structural, their equations can be viewed as approximations to the decision rules relating work and leisure choices to state variables that would arise in a fully specified model of lifetime utility maximization. In this interpretation, the parameters in the equations of Altonji, Smith, & Vidangos (2013) depend on an underlying set of coefficients that describe a worker's preference for leisure, job search technology, and other economic fundamentals.

Human capital valuation, however, requires a discount rate to translate future labor income flows into a certainty equivalent of wealth (Equation 8). To this end, the hours/wages processes estimated by Altonji, Smith & Vidangos (2013) could be used in the calibration of a life-cycle model that is more general and flexible than those discussed in Section 2.3. Alternatively, one could pursue the estimation of a structural life-cycle model that includes some features of the specifications of Altonji, Smith & Vidangos (2013). Recent work by Low, Meghir & Pistaferri (2010) is a major step in this direction. The authors explore a structural life-cycle model of consumption, labor supply, and job mobility in an economy with search frictions. The fundamental sources of risk in their model include shocks to individual productivity, job arrival shocks when employed and unemployed, and firm-level shocks that lead to job destruction. They go on to empirically quantify such risks in the presence of labor market frictions and conclude that allowing for job mobility has a large effect on the estimate of productivity risk. Exploring the implications of these results for the value and risk of human capital is a promising area of future work.[3]

3.2. Human Capital Investment

The results of Brown, Fang & Gomes (2012) that we discuss in Section 2.3 show that a great deal of cross-sectional variation in the value of human capital is linked to a worker's education. Brown et al., however, take age-earnings profiles conditional on education as given, rather than focusing on a worker's choice to pursue education over the life cycle. Also, they abstract from other forms of investment in human capital, such as training, early childhood intervention, and medical care.

[3] Several studies in the financial economics literature explore life-cycle portfolio choice models with a work/leisure trade-off and retirement decisions (e.g., Bodie, Merton & Samuelson 1992; Bodie et al. 2004; Farhi & Panageas 2007; Dybvig & Liu 2010). Their focus is on the effect of variable labor supply on stock market holdings.

The idea of human capital investment goes back to the seminal work of Becker (1964). To understand the incentives for such investment and the implications for wages and earnings, it is useful to articulate the uses of human capital in the production process of a firm. For example, Becker (1964) thinks of human capital as the stock of knowledge and skills embodied in a worker and used by the firm as an input. Other views have subsequently emerged (e.g., Acemoglu & Autor 2011). The first is the Gardener view, named after the proponent of the multi-intelligence theory that distinguishes between, e.g., mental and physical abilities, which attributes similar dimensions to human capital. Acemoglu & Autor (2011) call the second view the Schultz/Nelson–Phelps view, which thinks of human capital as the capacity to adapt to a changing environment. Third, the Bowles–Gintis view identifies human capital with the ability to follow directions and work in hierarchical organizations. Although these previous interpretations are similar in many respects, the fourth one, which Acemoglu & Autor (2011) call the Spence view, stands out because it considers observable measures of human capital (e.g., education) as a signal of ability rather than a useful production factor.

Alternative interpretations of the uses of human capital imply different investment incentives. For instance, in the Spence view, a costly investment in education is worthwhile if it allows a high-ability worker to signal his or her type to an imperfectly informed employer, whereas in the Becker view, education produces knowledge that directly increases a person's productivity. More broadly, this distinction determines the way we think of the different components of human capital. These include innate ability, schooling and training, and other factors such as school quality, environment, and peer effects.

3.2.1. Schooling and training. Most of the theoretical work on schooling and training draws on Becker's (1964) view that education makes people more productive. The basic idea in this literature is that people with different innate ability face the trade-off of paying for education (in the form of tuition fees and forgone income) to acquire skills that will increase their future productivity and salary. People with higher ability experience a higher return to education (other things being equal) and therefore have a stronger incentive to invest in human capital. With perfect capital markets, workers can finance the cost of schooling and thus obtain their optimal level of education. In the presence of market imperfections such as credit constraints, access to borrowing is limited. This causes constrained individuals to invest less, stopping their schooling when the marginal return is still relatively high (e.g., Lochner & Monge-Naranjo 2012).

In addition to attending school, a worker can pursue more education after beginning employment. The seminal contribution of Ben-Porath (1967) includes knowledge depreciation and studies human capital accumulation in the form of postschool training. His model underscores the continuity of investment in education during and after the school years. He finds that the optimal investment in human capital has a declining pattern that goes to zero as the worker approaches retirement, as at that time the opportunity cost of forgoing wages for more training outweighs the benefit of future productivity gains. These results are consistent with the hump-shaped earnings profile that workers typically experience over their life cycle and with the hump-shaped profile in human capital.

In contrast to the notion that schooling produces skill, Spence (1973) views education as a signal that high-ability workers use to convey their type to uninformed employers and therefore secure a higher salary. To obtain a separating equilibrium, it is important that high-ability workers face a lower cost to invest in human capital than low-ability people, so that they can attain a level of education that is too costly for low-ability workers given the salary differential between the two ability types. However, pooling equilibria are also possible, though they can often be ruled out by appropriately restricting the concept of equilibrium (e.g., Cho & Kreps 1987).

There is a positive correlation between the education level and the earnings of a worker. However, labor economists have been careful about drawing the conclusion that more education causes higher earnings. First, the most productive workers are those who also have the strongest incentive to pursue more years of education, i.e., there could be an ability bias. This is consistent with Becker's (1964) view of human capital theory, where more able workers benefit more from longer schooling. But it is also consistent with Spence's (1973) view, where workers use education as a signal. Second, there could be a selection bias, as people tend to study fields in which they are most efficient and motivated. A vast literature deals with these biases by studying the linkage between earnings and education in a sample of identical twins. Based on the evidence of these studies, Card (1999) concludes that the ability bias is rather small.[4]

The findings of this empirical literature suggest that one additional year of schooling yields a 6–15% increase in a worker's annual salary (e.g., Card 1999).[5] This evidence is consistent with Becker's (1964) view that education makes workers more productive. Testing Spence's (1973) signaling view is more challenging. In both Becker's and Spence's views, part of the difference in earnings between high- and low-education workers is because of differences in ability. However, in Becker's theory, ability may be unobserved by the econometrician but is known to the employer, whereas in the signaling theory, it is unobserved by employers as well as by the econometrician. Acemoglu & Autor (2011) review empirical studies that attempt to gauge the signaling return to education. Overall, there is some evidence for the signaling channel, although the strength of the effect is hard to quantify.

The evidence of credit constraints on schooling decisions is also mixed. The comprehensive survey by Lochner & Monge-Naranjo (2012) concludes that borrowing constraints had little effect on college attendance in the early 1980s. Since then, in the United States, both college attendance and tuition have risen much faster than credit limits of government-sponsored student loan programs. For instance, Lochner & Monge-Naranjo (2012) report that 26% of all dependent undergraduate students at four-year public universities in the United States were borrowing the maximum allowable amount from the Stafford Loan Program in 1999–2000, compared with fewer than 4% of students 10 years earlier. The private sector has stepped in to meet, at least partly, the increasing credit demand. Lochner & Monge-Naranjo note that private student credit increased rapidly from virtually zero in the early 1990s to 9% of all student loan dollars distributed in 1999–2000. Taken together, this evidence suggests that, in recent years, credit constraints have become more important for higher education decisions in the United States. These constraints could impact not only educational attainment but also college quality, work/consumption decisions while in school, and saving/investment decisions (e.g., Palacios-Huerta 2003; Saks & Shore 2005; Roussanov 2010; Athreya, Ionescu & Neelakantan 2013). Finally, extending credit for human capital requires repayment enforceability and raises other incentive problems (e.g., Lochner & Monge-Naranjo 2011).

[4]Other research has relied on instrumental variable (IV) regressions based on institutional changes in the education system to establish a causal link between education and earnings. Card (1999) summarizes the evidence in this literature and reports that the estimated returns to schooling via IV regressions are 20–40% above the corresponding ordinary least-squares estimates. Card's interpretation of this evidence is that the marginal returns to schooling for certain subgroups of the population—particularly those whose schooling decisions are most affected by structural innovations in the school system—are somewhat higher than the average marginal returns to education in the population as a whole.

[5]Although these estimates imply that education significantly raises future earnings, it is worth underscoring that the R^2 of these regression is typically small, which suggests that there are determinants other than years of schooling that explain variation in earnings.

3.2.2. Early childhood investment. Although there is extensive work on the returns to school and college education investment, only recently has the human capital literature started to focus on the long-term effects of early childhood education (e.g., Cunha et al. 2006, Almond & Currie 2011). This research finds that early childhood intervention among children with disadvantaged backgrounds leads to higher test scores, decreased grade retention, decreased time in special education, decreased crime and delinquency, and increased high school graduation rates. This new wave of research stresses the need for a better understanding of the life-cycle skill formation process. It differentiates between early and late investments in human capital. Moreover, it recognizes the roles of both cognitive abilities and noncognitive ones (e.g., perseverance, self-control, reliability, consistency, motivation, and optimism) in determining the returns to human capital (Cunha & Heckman 2007, 2008; Cunha, Heckman & Schennach 2010). In this setup, the skill production technology exhibits dynamic complementarity (early investments increase the productivity of later investments) and self-productivity (skills acquired in the early stage augment skills acquired in later stages). These two features produce multiplier effects: Skills acquired today beget more skills in the future. According to this literature, effective public policies would focus on young children's human capital investments, as they have the highest return compared with investments in later years. Moreover, such policies may potentially reduce lifetime inequality, as differences in early life conditions have been found to explain a significant portion of the variation in lifetime earnings and wealth (Huggett, Yaron & Ventura 2006, 2011).

However, some low-income families do not make the same investment in early childhood programs as higher-income families do. One possible explanation is the presence of borrowing constraints. Indeed, an increase in family income at early childhood ages has a greater effect on educational achievement than income received at later ages (e.g., Dahl & Lochner 2012). This finding is consistent with the dynamic complementarities discussed above: Higher early investment leads to higher returns for later investments in education, whereas it is difficult to amend inadequate levels of early investments with higher investments later in life (Cameron & Heckman 1998, Keane & Wolpin 2001). In an overlapping generations model of human capital production, Caucutt & Lochner (2012) show that relaxing credit constraints on young parents would increase both early investments in young children and late investments in older children. In contrast, a policy that focuses on subsidizing college education alone might not be as effective in increasing human capital investment. The effect on future generations, however, is more ambiguous. Increased borrowing causes higher debt levels that result in parents transferring fewer resources to their children in the long run. This in turn could limit the ability of future generations to sustain the same increased level of human capital investment.

This discussion underscores that the timing of human capital investment over the life cycle is important. Early childhood investment is critical, but it is highly illiquid and requires significant time and financial costs. Lochner & Monge-Naranjo (2012) argue that the constraints faced by parents when investing in early childhood education are more pervasive and harmful than the constraints that people face at college ages. The findings of this literature provide support for public policies that facilitate access to early childhood education, especially for underprivileged households. For instance, Restuccia & Urrutia (2004) conclude that social programs that help finance early education have a larger impact on earnings mobility than an increase in college subsidies.

3.3. Health Shocks

Individual health has a broad effect on most lifetime labor market outcomes, including wages, earnings, labor force participation, hours worked, and retirement. Thus, the literature views health as a component of human capital (e.g., Becker 1964). Although it is intuitive that a large negative health shock can lead to a decline in lifetime earnings, numerous empirical studies have struggled to gauge the magnitude of these changes.

In their survey, Currie & Madrian (1999) discuss three main issues that are important to disentangle the effect of health status on labor market outcomes. First, it is difficult to measure health shocks. Thus, estimates differ based on measures of health being used (e.g., mental health, heart diseases, external accidents). Second, there is a vast cross-disciplinary literature that argues that individual socioeconomic status (e.g., education and wealth) determines the investment in a person's health and, thus, health capital (e.g., Smith 1999). Third, because health and labor market outcomes are endogenous variables, estimates of the effect of a health shock on wages, and vice versa, are sensitive to identification assumptions (e.g., Lee 1982; Haveman, Wolfe & Huang 1994; Riphahn 1999; Au, Crossley & Schellhorn 2005; Disney, Emmerson & Wakefield 2006).

In general, these studies focus on the adult population to determine the relationship between health and labor market activity. But there is also growing evidence that a person's early childhood environment significantly influences later life outcomes. Almond & Currie (2011) provide an extensive summary of recent work. The main finding of this literature is that shocks before age five lead to significant long-term consequences. In particular, poor health in childhood affects both adult health status and investments in other forms of human capital (such as education). Even a compromised prenatal environment can have long-term negative effects on future health outcomes (e.g., Barker & Osmond 1986, Kraemer 2000, Almond & Mazumder 2011). Furthermore, there is evidence that poor health in childhood is associated with reduced educational attainment as well as lower wages and labor force participation (e.g., Grossman 1975, Perri 1984, Wolfe 1985, Wadsworth 1986, Smith 2009).

This discussion suggests that health shocks could have a significant impact on lifetime earnings. Moreover, the dynamics of health and health insurance coverage (e.g., De Nardi, French & Jones 2013) affect the price of health care relative to nonhealth consumption and therefore the rate at which workers discount future labor income flows. Yogo (2009) builds on these ideas with a life-cycle model in which a retiree faces stochastic health depreciation, which affects the retiree's marginal utility of consumption and life expectancy. The retiree receives income (including Social Security) and chooses consumption, health expenditure, and allocation of wealth among bonds, stocks, and housing to maximize lifetime utility. Yogo's focus is on explaining the cross-sectional variation and the joint dynamics of health expenditure, health, and wealth for retired workers (for studies of the interaction between retirement decisions and uncertain health status, see French 2005, van der Klaauw & Wolpin 2008, French & Jones 2011, Cocco & Gomes 2012). Extending his work to the life-cycle problem of a young worker is a promising step toward a better understanding of the value and risk of human capital in the presence of health shocks.

3.4. Aggregate Versus Idiosyncratic Labor Income Shocks

Extended periods of strong economic activity are likely to be associated with sustained earnings growth, and vice versa. Hence, it is natural to conjecture the presence of dependence between labor income shocks and aggregate economic fluctuations. Here we review the literature that studies different channels through which economic shocks might propagate into a worker's earnings and discuss the implications for the value and risk of human capital. We focus, in particular, on articles that use stock market performance as a proxy for economic conditions and explore short- versus long-run correlations between stock returns and earnings.

3.4.1. Contemporaneous correlation. Various authors explore the effect of contemporaneous correlation between labor income and stock market innovations (Campbell et al. 2001; Viceira

2001; Cocco, Gomes & Maenhout 2005; Gomes & Michaelides 2005). They assume that logarithmic labor income is the sum of a deterministic component, permanent idiosyncratic shocks ν_i, and transient shocks ε_i; this is similar to Equations 1 and 2 but with random walk dynamics for ν_i:

$$\nu_{i,t} = \nu_{i,t-1} + u_{i,t}. \tag{9}$$

These authors decompose the permanent shock $u_{i,t}$ into an aggregate component ξ_t distributed as $N(0, \sigma_\xi^2)$ and an idiosyncratic component $\omega_{i,t}$ distributed as $N(0, \sigma_\omega^2)$:

$$u_{i,t} = \xi_t + \omega_{i,t}. \tag{10}$$

They then introduce the stock market portfolio S with total return

$$r_t = \log S_t - \log S_{t-1} = \mu_s + \eta_t, \tag{11}$$

where η_t denotes $N(0, \sigma_\eta^2)$ innovations that are i.i.d. over time.

This framework allows for contemporaneous correlations between stock market shocks η_t and aggregate labor income shocks ξ_t. Empirical support for this channel, however, is limited. Early work by Davis & Willen (2000) obtains estimates for the coefficient $\rho = \text{corr}(\eta_t, \xi_t)$ of between 0.1 and 0.3 for college-educated males and -0.25 for male high school dropouts. More recently, Cocco, Gomes & Maenhout (2005) estimate ρ to be nearly zero, i.e., they do not find a significant contemporaneous correlation between stock market returns and permanent labor income shocks. Campbell et al. (2001) also find extremely low and insignificant contemporaneous correlations across households with different levels of education; their estimates are higher only when computed on excess stock returns lagged one year. Entrepreneurial risk, however, correlates more highly with stock market risk; for instance, Heaton & Lucas (2000) find that the correlation between the quarterly growth rate of real nonfarm proprietary income (as reported in the National Income and Product Accounts) and the value-weighted return from the Center for Research in Security Prices is 0.14, whereas the correlation between the value-weighted return and the quarterly growth rate of real aggregate wages is -0.07.

3.4.2. Countercyclical volatility of idiosyncratic shocks. Storesletten, Telmer & Yaron (2004) consider a model with persistent idiosyncratic shocks $u_{i,t}$ (as in Equation 2) with variance $\sigma_{u,t}^2$ that is common across agents and varies over the business cycle:

$$\sigma_{u,t}^2 = \begin{cases} \sigma_{u_E}^2 & \text{if there is aggregate expansion at date } t, \\ \sigma_{u_C}^2 & \text{if there is aggregate contraction at date } t. \end{cases} \tag{12}$$

They estimate the model on PSID data from 1968 to 1993 via the generalized method of moments. They find idiosyncratic risk to be (*a*) highly persistent, with an annual autocorrelation coefficient $\phi = 0.95$, and (*b*) strongly countercyclical, with a conditional standard deviation that increases by 75% (from $\sigma_{u_E}^2 = 0.12$ in an expansion to $\sigma_{u_C}^2 = 0.21$ in a contraction) as the macroeconomy moves from peak to trough. Their estimates translate into contraction/expansion conditional standard deviations of \$9,500 and \$5,300, based on the average worker's 2002 dollar earnings of \$45,000. These computations are useful to gauge the impact of idiosyncratic risk on a person's earnings and how shocks vary over the business cycle.

3.4.3. Procyclical mean of labor income growth. Lynch & Tan (2011) extend the framework of Storesletten, Telmer & Yaron (2004) to allow for fluctuations in the conditional mean of the labor income flow at business cycle frequencies. They use the dividend yield D on a stock market portfolio as a proxy for the business cycle and assume that $d_t = \log(1 + D_t)$ follows a mean-reverting process:

$$d_t = \mu_d + b_d\, d_{t-1} + \varepsilon_t, \tag{13}$$

where ε_t denotes an $N(0, \sigma_\varepsilon^2)$ i.i.d. shock. In their model, the conditional means of both the stock market return and the permanent component of labor income are linear functions of the d_t predictor:

$$\begin{aligned} r_t &= \mu_s + b_s\, d_t + \eta_t, \\ v_{i,t} &= v_{i,t-1} + \mu_v + b_v\, d_t + u_{i,t}, \end{aligned} \tag{14}$$

where η_t and $u_{i,t}$ are mean-zero Gaussian i.i.d. innovations with variances σ_η^2 and σ_u^2, respectively.

Using data on retail trade income growth and the 12-month dividend yield on the value-weighted New York Stock Exchange index, Lynch & Tan (2011) estimate $b_v < 0$, $b_s > 0$, and b_d close to one. That is, they find that the permanent component of labor income is procyclical, whereas the dividend yield is countercyclical. Like Storesletten, Telmer & Yaron (2004), they find countercyclical fluctuations in the volatility of idiosyncratic shocks.

3.4.4. Cointegration between labor income and stock market returns. Several studies explore the effect of long-run codependence between aggregate economic conditions and labor income. It is straightforward to incorporate this feature into the framework that we review here in the form of cointegration between labor income and stock returns or between labor income and aggregate economic activity (e.g., Campbell 1996; Baxter & Jermann 1997; Lucas & Zeldes 2006; Santos & Veronesi 2006; Benzoni, Collin-Dufresne & Goldstein 2007; Huggett & Kaplan 2013). To this end, it is convenient to specify the logarithmic labor income process $y_{i,t} = \log(Y_{i,t})$ as the sum of aggregate y^A and idiosyncratic y_i^I components,

$$y_i = y^A + y_i^I. \tag{15}$$

Similar to Equation 1, the idiosyncratic labor income component contains deterministic and stochastic terms:

$$y_i^I = f(t, Z_{i,t}) + v_{i,t}^I + \varepsilon_{i,t}. \tag{16}$$

As in, e.g., Cocco, Gomes & Maenhout (2005), the $v_{i,t}^I$ process follows a random walk with i.i.d. error $\omega_{i,t}$,

$$v_{i,t}^I = v_{i,t-1}^I + \omega_{i,t}, \tag{17}$$

and $\varepsilon_{i,t}$ is a transient i.i.d. shock.

To capture deviations between aggregate labor income and stock market values, we introduce a variable $h = y^A - s$, where $s = \log(S)$ is the logarithmic price of the stock market portfolio with return $r_t = \Delta s_t$ given in Equation 11. Although there may be short-run deviations between aggregate earnings and stock market values, it is natural to conjecture that a sustained period of high economic growth will result in strong stock and labor market performances, so that these two markets will move together in the long run. To generate this type of comovement in the model, we assume that y^A and s are cointegrated with a time trend, i.e., h is trend stationary with dynamics[6]

$$\Delta h_t = \kappa(\theta\, t - h_t) + z_t - \sigma_{h_\eta}\, \eta_t, \tag{18}$$

where z_t is an $N(0, \sigma_z^2)$ i.i.d. shock that is independent of the stock market innovation η_t. The coefficient κ measures the speed of mean reversion for the cointegration relation. In particular,

[6]The model in Equation 18 is mathematically equivalent to an alternative specification with $h = y^A - d - \overline{y^A d}$, where d is the logarithmic dividend process, $\overline{y^A d}$ is the long-run log-ratio of aggregate labor income to dividends, and h is a stationary mean-reverting process with no time trend (e.g., Benzoni, Collin-Dufresne & Goldstein 2007).

$\tau = (\log 2)/\kappa$ is the half-life of shocks to h; larger values of κ imply a faster decay toward the long-run trend θt.

In first differences, the labor income process is

$$\Delta y_{i,t} = \Delta y_t^A + \Delta y_{i,t}^I. \tag{19}$$

Substituting $\Delta y^A = \Delta h + \Delta s$ into Equation 19 yields an expression for the total labor income dynamics,

$$\Delta y_{i,t} = -\kappa h_t + \kappa\theta t + \Delta f(t, Z_{i,t}) + \xi_t + \omega_{i,t} + \Delta\varepsilon_{i,t}, \tag{20}$$

where, as in Cocco, Gomes & Maenhout (2005), we can interpret $\xi_t = z_t + (1 - \sigma_{h_\eta})\eta_t$ as a Gaussian i.i.d. shock to the aggregate component of labor income with mean zero and variance $\sigma_\xi^2 = \sigma_z^2 + (1 - \sigma_{h_\eta})^2\sigma_\eta^2$ (see, e.g., Benzoni & Chyruk 2009).

The model of Cocco, Gomes & Maenhout (2005) is a special case of this framework. In the limit when the mean reversion parameter $\kappa \to 0$, Equation 20 collapses into the expression for their labor income process in first differences. As in Cocco, Gomes & Maenhout (2005), the labor income model described by Equation 20 allows for contemporaneous correlation between labor income and stock market shocks,

$$\mathrm{corr}(\xi_t, \eta_t) = \frac{(1 - \sigma_{h_\eta})\sigma_\eta}{\sqrt{\sigma_z^2 + (1 - \sigma_{h_\eta})^2\sigma_\eta^2}}. \tag{21}$$

This correlation can be set equal to the value of the ρ correlation coefficient estimated by, e.g., Cocco, Gomes & Maenhout (2005) with an appropriate choice of σ_{h_η}. However, this framework also allows for nonzero long-run correlations between labor income and stock market returns that can be large even if the contemporaneous correlation is small. In particular, when $\sigma_{h_\eta} = 1$, the contemporaneous correlation in Equation 21 is zero, yet the long-run correlations driven by the cointegrating variable h are positive when $\kappa > 0$.

Several articles explore a cointegration relation similar to Equation 18. For instance, Baxter & Jermann (1997) study the correlation in returns to human and physical capital using annual data on labor income and capital income for Japan, Germany, the United Kingdom, and the United States over the period 1960–1993. They measure labor income as total employee compensation, with capital income being GDP at factor cost minus employee compensation. For each country, they find that domestic human capital returns are strongly correlated with the returns to domestic physical capital. However, they report only weak evidence that labor and physical capital income are cointegrated. Benzoni, Collin-Dufresne & Goldstein (2007) explore the cointegration relation between labor income and aggregate stock market dividends, and Huggett & Kaplan (2013) focus on labor income and stock market returns. Also in these cases, the evidence for cointegration is limited, with results that are sensitive to the choice of the sample period.

Although the empirical evidence in its support is weak, it is nonetheless worthwhile to investigate cointegration between labor income and stock market returns as a possible source of aggregate risk in individual earnings. First, the tests used to reject the null hypothesis of a unit root in Equation 18 are notorious for lacking power. This limitation could well explain the lack of empirical support for cointegration. Second, economic intuition suggests that returns to human and physical capital should be correlated.[7] Third, empirical evidence suggests that capital and

[7] Lustig & Van Nieuwerburgh (2008) reach conclusions at odds with this intuition. They use a representative agent model with recursive utility and observed aggregate consumption to back out consumption innovations that cannot be attributed to news about current or future financial returns. They attribute such innovations to the returns on human wealth and find

labor income shares fluctuate over time. A model with cointegration accommodates this evidence by allowing for short-term variation in factor shares while retaining the long-run restriction that factor shares are stationary. This is a desirable feature; as Baxter & Jermann (1997) point out, if labor and capital income were allowed to have independent trends, then the ratio of labor income to capital income would either grow without bound or approach zero asymptotically, and the labor share would approach either zero or one. This seems unlikely and counterfactual.

3.4.5. Implications for human capital valuation and risk. One of the channels through which economic conditions could affect individual labor income is the contemporaneous correlation between aggregate earning shocks and stock market returns, denoted by the coefficient ρ in Section 3.4.1. Empirical support for this channel is weak. For instance, Cocco, Gomes & Maenhout (2005) report estimates of ρ that are close to zero and statistically insignificant. They then go on to solve the life-cycle problem of a worker when the correlation coefficient between labor income and stock market risk is set at their small estimate. Their main conclusion is that in this setting, labor income acts as a substitute for risk-free asset holdings, a finding that confirms earlier results obtained by Heaton & Lucas (1997) in an infinite-horizon model.

In contrast, several studies find comovements between labor income and stock returns at business cycle frequencies to have a significant effect on the value and risk of human capital. For instance, Storesletten, Telmer & Yaron (2007) consider an overlapping generations model in which idiosyncratic labor income risk is subject to countercyclical variation, a feature documented in Storesletten, Telmer & Yaron (2004) and discussed in Section 3.4.2. In this setting, they show that the distribution of aggregate risk affects portfolio holdings in the economy, giving rise to a hump-shaped risky asset share of financial wealth over a worker's life cycle. This is because, in their model, human capital acquires stock-like features owing to the cyclical component in the variance of earnings. For workers exposed to stock market risk via the implicit stock position embedded in human capital, it is optimal for them to reduce their direct stock holdings, especially when they are young and most of their wealth is tied up in future labor income. Lynch & Tan (2011) confirm the results of Storesletten, Telmer & Yaron (2007) and extend them to a model that, in addition to countercyclical idiosyncratic volatility, also features procyclical labor income growth (see the discussion in Section 3.4.3).

Benzoni, Collin-Dufresne & Goldstein (2007) obtain similar results in a model that features cointegration between the aggregate component of labor income and dividends. Also in this case, long-run comovements between stock returns and earnings expose workers to market risk, and human capital displays a stock-like component, especially when the worker is young.[8] Huggett & Kaplan (2013) consider a more general framework that includes all channels of exposure of labor income to aggregate risk, among which they favor countercyclical variation in idiosyncratic labor income risk. They also find a stock component in human capital, although it is not as large as the one reported in Benzoni, Collin-Dufresne & Goldstein (2007).

them to be negatively correlated with shocks to financial asset returns. Their results, however, may be sensitive to model assumptions; for instance, Bansal et al. (2014) argue that extending their model to include stochastic macroeconomic volatility results in a positive correlation between returns to human capital and financial wealth.

[8]Lucas & Zeldes (2006) consider a similar model for the valuation and hedging of defined-benefit plans (see also Lucas & Zeldes 2009). Geanakoplos & Zeldes (2010) study the effect of cointegration between labor income and stock returns on the valuation of Social Security obligations. Retirement benefits for active workers depend on the realization of the future economy-wide wage level. If wages and stock returns correlate positively over the long run, retirement benefits contain an aggregate risk component and should therefore be discounted at a rate that accounts for that risk.

Overall, the evidence discussed here suggests that labor income risk contains an aggregate component that affects long-run fluctuations in earnings. It is difficult, however, to assess the magnitude of this component with data that span only a few decades. For the same reason, it is hard to disentangle the different channels through which aggregate risk spills into individual labor income. Despite these challenges, these issues are worth further investigation. These efforts help us to better understand the sources of risk in human capital and to identify a discount rate that accurately reflects the riskiness of future labor income flows. Further, different occupations may expose workers to various degrees of aggregate shocks. This applies to people employed across different industries as well as to self-employed workers and entrepreneurs (Heaton & Lucas 2000). Hence, heterogeneity in the exposure to aggregate risk could be an important source of cross-sectional variation in human capital valuation.

4. CONCLUSIONS

In this article, we review the theoretical and empirical literature that models a worker's life-cycle earnings and identifies appropriate discount rates to translate those cash flows into a measure of human capital value. The main points of our discussion can be summarized as follows:

1. Because of various market imperfections, there is no trading in explicit claims on future labor income flows. Because workers are exposed to labor income shocks that cannot be hedged with traded assets, the valuation of human capital is specific to each worker, who embodies the set of values and skills that contribute to the worker's productivity. Hence, we focus on a worker's private valuation of human capital, defined as the implicit value of future earnings discounted at the worker's intertemporal marginal rate of substitution.
2. A vast literature abstracts from work/leisure decisions and models a worker's earnings as an exogenous univariate process that includes a deterministic component as well as persistent (or permanent) and transient shocks. The estimated earnings process discounted at risk-adjusted rates implies that the value of human capital exhibits a hump-shaped profile over the worker's life cycle. Variation in workers' characteristics such as gender, race, risk preferences, marital status, and education accounts for a great deal of cross-sectional heterogeneity in human capital valuation.
3. A new wave of research explores the economic sources of risk that underlie shocks to earnings and explicitly models a worker's work/leisure and retirement decisions. This literature has been successful at linking labor income fluctuations to shocks to individual productivity, health shocks, job arrival shocks, and firm-level shocks that may lead to job creation or destruction. In turn, these findings help us better understand the sources of risk in a worker's human capital.
4. The value of a person's human capital depends on the education and training acquired over the life cycle. The benefits are not limited to college education, as recent research stresses the importance of early childhood investment. The rise in college tuition has deepened concerns that people might be obtaining a suboptimal level and quality of education, and that they could be forced to consume less and work more during their college years. Although the evidence on the effect of borrowing limits on college attendance is mixed, credit constraints are likely to be a bigger impediment for early childhood investment. Public policy experiments suggest that social programs that help finance early education have a larger impact on earnings mobility than an increase in college subsidies.
5. There is little evidence of contemporaneous correlation between labor income fluctuations and stock market returns. In contrast, long-run dependencies between labor income and

stock returns are a potentially important channel that exposes human capital to aggregate economic risk. These low-frequency comovements are hard to quantify with data that span a relatively short period of time, but in model calibrations they can have a significant impact on the valuation of human capital. When the stock and labor markets comove in the long run, human capital acquires stock-like properties, especially for young workers who are exposed the most to long-run labor income risk.

Despite the progress that has been made, much work is still to be done. Issues that are worth further investigation include the following:

1. Although our discussion focuses on private valuation, human capital could also include a significant social component. For instance, an increase in the human capital of an individual worker might create positive nonpecuniary externalities, such as better citizens or lower crime, and raise the productivity of other workers around him or her and therefore increase aggregate productivity in the economy. Also, in the presence of complementarity in production factors, wider availability of human capital might induce firms to increase their investment in physical capital and might thus result in higher wages (e.g., Acemoglu 1996). For these reasons, the social return to human capital could exceed the private return. In contrast, if education is merely a signal of a worker's ability, then the social return to the investment in education could be lower than the private return, because high-ability workers might generate a negative externality for other workers by pursuing more schooling, which will be rewarded with higher wages.[9]
2. The measure of human capital that we discuss here is based on the valuation of lifetime earnings generated by the worker. However, earnings are an imprecise measure of a worker's skills. Although attributing differences in earnings, and therefore the value of human capital, to unobserved skill heterogeneity is a useful starting point, this approach is reductive (e.g., Acemoglu & Autor 2011). For instance, differences in compensation may be explained by hard-to-measure job characteristics that could make a job appealing, even if it pays a low salary. Second, the productivity of two jobs may be different, and workers in those two positions could be paid a different salary despite having similar skills. Third, workers might face wage discrimination because of employers' prejudices against, e.g., race, gender, or religion. These considerations suggest that human capital valuation should be based on a broader measure of cash flows associated with workers' output, rather than on observed earnings.
3. Over the years, education has been one of the main targets of social policies aimed at fostering the production of human capital and bridging income inequality. The success of these programs hinges on the ability of policy makers to use limited resources effectively. Understanding how to better design such programs is the topic of much ongoing research, including many of the contributions we discuss here. An important part of this agenda is the study of the role of education in the production of human capital (early childhood investment versus schooling and subsequent job training). Furthermore, possible credit constraints motivate policies (e.g., student loans and various subsidies) that promote the accessibility of education. A better grasp of the human capital production function and of skill formation could form the basis for more effective school programs and curricula, teachers' training, and investment in premises and teaching technology.

[9] See, e.g., Lange & Topel (2006) for a review of the literature on the social returns to the accumulation of human capital and, in particular, the social returns to education.

4. Finally, the studies that we review suggest that there is a linkage between health shocks and earnings. More work on this topic could help policy makers develop improved health and preventive care programs aimed at raising the private and social value of human capital and improving the management of human capital risks.

DISCLOSURE STATEMENT

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