# An Empirical Analysis of Risk Aversion and Income Growth

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Risk aversion enters many theoretical models of human capital investment, but attitudes toward risk have not been incorporated in empirical models of human capital investment. This article develops a model of the joint investment in financial wealth and human wealth to show that human capital investment is an inverse function of the degree of relative risk aversion. Using data from the Survey of Consumer Finances, I find that wage growth is positively correlated with preferences for risk taking. More-educated individuals are also more likely to be risk takers, thus risk taking explains a portion of the returns to education.

## I. Introduction

Individuals regularly face risky human capital investment decisions during their careers. Managers consider making new investments in learning new methods of managing; professionals decide whether to update their skills or invest in new ones. The reward for successful investing is promotion and pay increases—the penalty for failure is job loss or wage stagnation. Less skilled workers also choose between investment options,

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though investing is likely to be less common for them than for skilled workers. The choices all workers make are often between risky firm-specific investments, which are not transferable across firms, and more general occupation- and industry-specific investments on the job, which are transferable and hence less risky on average. However, even general occupational and industry investments are risky—note the decline of aeronautical engineering in the 1970s and the decline of the steel industry in the 1980s.

All of these types of human capital investments are risky because the returns to investing are subject to two types of uncertainty: the uncertainty of unknown personal abilities, such as creativity and interpersonal skills, and the uncertainty of the firm's future payoffs for these skills. The methods of reducing riskiness that are available in financial markets, namely, diversification, exchange, and insurance, are not options for reducing the riskiness of returns to human capital investments. Diversification is ruled out since each individual typically holds only one job in which to invest. Exchange, which entails the selling of ownership to other parties, is ruled out by antislavery laws. Insurance is common in labor markets, and it may be provided by employers implicitly (Azariadis 1975),[1] but it cannot be used to reduce risk due to unknown personal abilities—clear problems of moral hazard would arise if firms attempted to insure against this type of endogenous risk.[2]

Given that human capital investments are subject to these noninsurable, nondiversifiable risks, one would expect the degree to which an individual is risk averse to have a large effect on the individual's decisions to invest in risky human capital. Theoretical models of human capital investments have long recognized the importance of risk aversion in models of employer change (Johnson 1978), migration (David 1974), occupational choice (Levhari and Weiss 1974), choice of hazardous work environments

[1] Since the work of Azariadis (1975), researchers have suggested that risk-averse workers may enter into implicit or explicit contracts with the firm to stabilize earnings (when earnings vary unpredictably because of demand-side shocks). If firms are less risk averse than workers, because shareholders hold a diversified portfolio, firms can effectively insure workers from temporal income fluctuations by offering implicit contracts in which workers pay a premium during good times and receive a payment during bad times. Firms, rather than third-party insurers, offer the insurance, because firms control the employment decisions that would produce adverse selection and moral hazard problems for outside insurers.

[2] Firms can provide partial insurance from the risk of revealing unknown personal abilities. Gibbons and Murphy (1992) show that in a multiperiod model with unknown personal ability, risk aversion, and pay for performance, firms will tend to insure against poor draws of ability in early years of a career (by offering wages independent of ability) and then lower insurance in the later years by substituting pay for performance to induce effort.

(Thaler and Rosen 1975), and incentive contracts (Gibbons and Murphy 1992). But while the importance of risk aversion has long been recognized in theoretical models of human capital investment, as well as in both theoretical and empirical treatments of financial investment decisions, it has largely been ignored by economists testing labor market hypotheses concerning investments. Empirical models of human capital investments occasionally estimate a parameter of constant relative risk aversion, but virtually none include the interpersonal variation in risk aversion that may drive the investment outcome.[3] Its omission could bias the coefficient estimates of other variables with which it is correlated, such as education or the rate of time preference. Moreover, the inclusion of heterogeneity in risk aversion in empirical models is likely to become more important as economists increasingly turn toward structural models of decision making, where the results are generated by differences in tastes or technology. What has been lacking in previous empirical work by labor economists is an attempt to measure risk aversion and to incorporate it in empirical hypotheses.

In this article, predictions from a theoretical model of risky investing are combined with a unique data set to test empirical hypotheses regarding the importance of risk aversion in human capital investing and income growth. The theoretical model extends Merton's (1971) continuous-time portfolio allocation model to incorporate workers' decisions to invest in risky human capital assets in addition to their financial investment decisions. The primary empirical implication is that individuals who are risk averse are less likely to undertake risky human capital investments that pay higher expected future wage rates. The emphasis here is on the *heterogeneity* in personal risk aversion that will result in heterogeneity in human capital investments, leading to heterogeneity in income growth. In other words, these interpersonal differences in risk aversion should explain some of the previously unexplained interpersonal variance of income growth. An empirical model of wage growth as a function of worker heterogeneity in risk aversion and investing is derived and estimated.

The measurement of interpersonal differences in risk aversion is accomplished by making the key assumption that survey information on the

[3] Empirical models of compensating wage differentials generally assume that preferences are homogeneous. Models that do incorporate risk aversion estimate one parameter for the degree of constant relative risk averse—see Weiss (1972), Hause (1974), Abowd and Ashenfelter (1981), Hamermesh and Wolfe (1986), Brown and Rosen (1987), and Moore (1987), Murphy and Topel (1987). Four papers that do mention heterogeneity in risk aversion are Schwartz (1976), Viscusi (1979), Johnson (1980), and Shaw (1987). Viscusi estimates wealth effects that reflect risk aversion and liquidity constraints. Wealth effects have generally been the mechanism for introducing heterogeneity in risk aversion.

allocation of wealth to financial assets can be used to infer degrees of individual risk aversion that are also applicable to human capital investment decisions. This assumption merely reflects a standard assumption in economics—that each individual possesses one concave utility function. Thus, in Section II, a model of the joint allocation of wealth to human capital investments and to financial investments is used to develop the empirical hypothesis that risk takers have higher expected income growth rates. The empirical results in Section III use individual longitudinal data from the Survey of Consumer Finances to estimate a nonlinear model of wage growth as a function of heterogeneity in risk aversion and human capital investment. The empirical results support the hypothesis that risk takers are rewarded with higher wage growth rates. In addition, the returns to risk taking are greatest among the more highly educated risk takers. Further results are discussed in the conclusion.

## II. The Investment in Risky Human Capital

In this section, the decision to invest in risky human capital assets is combined with the decision to invest in risky financial assets, in a continuous-time portfolio allocation model that is an extension of Merton (1971) and a special case of Williams (1979). The first-order conditions for this model produce an intuitively appealing analogy between human capital investment and the allocation of financial wealth to alternative assets. Define $s(t)$ as the share of current human capital, $K(t)$, that is allocated to producing new human capital at time $t$, and define $\alpha(t)$ as the share of financial wealth that is allocated to a portfolio of risky assets versus a risk-free asset. The optimal allocation equations are

$$s = \frac{\mu_h - \eta}{\sigma_h^2 R} \tag{1}$$

and

$$\alpha = \frac{\mu - r}{\sigma_f^2 R}, \tag{2}$$

where $\mu_h - \eta$ is the net return to risky human capital investment, $\mu - r$ is the net return to risky financial investments,[4] $\sigma_h^2$ and $\sigma_f^2$ are the variances of the risky returns, and $R$ is the Pratt-Arrow index of constant relative risk aversion. These equations are derived in appendix A.

[4] The net return to risky human investments, $\mu_h - \eta$, is more precisely equal to the difference between the return to human capital, $\mu_h$, and the marginal rate of substitution between financial wealth and human capital, $\eta$ (see app. A).

Focusing on the human capital investment decision and assuming that there is cross-individual heterogeneity in the degree of constant relative risk aversion $R$, equation (1) implies that risk-averse individuals will invest less in risky human capital. In addition, the greater the uncertainty surrounding the returns to these investments, $\sigma_h^2$, the more the risk-averse individuals will avoid them: as $\sigma_h^2 R$ rises, investment $s$ falls, unless the investor is compensated by a higher expected return, $\mu_h - \eta$.

The share of human wealth allocated to risky new investments, or $s$ in equation (1), is inherently unobservable, but it can be embedded in a wage growth equation to develop observable implications:

$$w_t = (1 - s_t)K_t = (1 - s_t)(1 + \gamma_t s_{t-1})K_{t-1},$$

$$w_{t-1} = (1 - s_{t-1})K_{t-1},$$

$$\Delta\ln w_t \approx \ln(1 + \gamma_t s_{t-1})$$

for $s_t \approx s_{t-1}$,

$$\Delta\ln w_t \approx \gamma_t s_{t-1} \tag{3}$$

for small $\gamma_t s_{t-1}$,

where $\gamma_t$ is the productivity of investment $s_{t-1}$. Because $s$, the share of human wealth currently invested in new human capital, is unobserved, substitute (1) into (3) to get the wage growth equation to be estimated (suppressing the $t$ subscripts):

$$\Delta\ln w = \gamma \frac{\mu_h - \eta}{\sigma_h^2 \mathrm{R}}. \tag{4}$$

The key variable, risk aversion, $R$, can be identified using the financial investment equation (2). Under the standard assumption that all investors have equivalent perceptions of market returns (Friend and Blume 1975), the term $(\mu - r)/\sigma_f^2$ in equation (2) is constant across individuals. Thus, the share of net worth invested in risky assets, $\alpha$, is an inverse function of the individual's degree of constant relative risk aversion. Equivalently, the only reason risky financial asset shares differ across investors is that investors have different degrees of risk aversion, so equation (2) states that $\alpha$ is a simple inverse function of $R$. Rewrite equation (2) as $\alpha = 1/bR$, where $b \equiv \sigma_f^2/(\mu - r)$ is constant across investors. Substitute for $R$ in equation (4) to get

$$\Delta\ln w = b\alpha\left(\frac{\gamma(\mu_h - \eta)}{\sigma_h^2}\right). \tag{5}$$

The term $\gamma(\mu_b - \eta)$ is equal to the productivity of skill investment, $\gamma$, times its expected return, $\mu_b - \eta$, and it is a function of the variables that are typically included in wage growth equations to represent these effects. Adding $i$ subscripts for individuals, assume there is an observed vector $\mathbf{X}$ such that

$$\gamma_i(\mu_{bi} - \eta_i) = \mathbf{X}_i\mathbf{A} + u_i, \tag{6}$$

where $u_i$ is independently and identically distributed (i.i.d.) and represents measurement error in expected gains. The wage growth equation to be estimated is

$$\Delta\ln w_i = \frac{b\alpha_i}{\sigma_{bi}^2}(\mathbf{X}_i\mathbf{A}) + e_i, \tag{7}$$

where the error term $e_i$ is $e_i = (b\alpha_i/\sigma_{bi}^2)u_i$, so that it must be tested for heteroscedasticity.

The intuition underlying equation (7) is that individuals with a larger share of financial wealth in risky assets, $\alpha_i$, are less risk averse and so will invest more in unobserved risky human capital. Thus, risk taking (as measured by $\alpha_i$) will shift upward all estimated returns to the human capital investment vector $\mathbf{X}_i$ by the amount $b/\sigma_{bi}^2$.

## III. Empirical Results

### A. Data Set

The joint analysis of income growth and financial wealth allocation is made possible by a fairly unique data set, the Survey of Consumer Finances (SCF). The SCF, developed by the Federal Reserve Board and six other agencies, surveyed 4,262 households in 1983, asking very detailed questions about assets, income, and employment for respondents and spouses. Included in this sample is a subsample of 438 nonrandom high-income households introduced into the sample because wealth issues are the focus of the survey and high-income households hold a disproportionate share of wealth. Approximately two-thirds of all households were resurveyed in 1986, and in our empirical analysis we limit the sample to employed individuals in the 21–64 years age range, producing a sample of 2,684 men and women. After conditioning on nonmissing data for assets and risk aversion, the sample falls to 2,199 men and women. This sample includes 212 high-income respondents, used in the regressions below with sampling weights.[5]

## B. Wage Growth

The estimation of equation (7) models real wage growth over a 3-year period, 1983–86, using the SCF data. The dependent variable is real hourly wage growth, rather than income growth, to separate the investment and labor supply decisions.[6] The right-hand-side variables are those described as components of the **X** vector in equation (7). The theoretical model of equation (6) identifies **X** as a vector of proxies for net rates of return to investments. Since there are very few proxies for individual differences in rates of return, **X** also contains proxies for quantities of investment. That is, the **X** vector in equation (7) is largely obtained by differencing a standard wage growth equation, producing **X** = {DTENURE, DTEN2, DEXP2, EDUC}, where in a standard wage regression these variables are proxies for quantities of and returns to investment. DTENURE is the 3-year change in tenure. Workers who change jobs or experience unemployment will have less than 3 years of tenure growth. A squared term picks up the decline in wage growth with tenure: DTEN2 $= (\text{TENURE}_{86})^2 - (\text{TENURE}_{83})^2$.[7] Analogous changes in experience, DEXPER, are equal to less than 3 years only if individuals are unemployed, so DEXPER proves to be too homogeneous to include in regressions, thus falling into the constant term. $\text{DEXP}^2 = (\text{EXPER}_{86})^2 - (\text{EXPER}_{83})^2$ is included. The proxies for expected rates of return to investment are education and the quadratic experience terms. Years of education, EDUC, is included under the hypothesis that highly educated workers are more likely to have higher returns to on-the-job investment if education and postschool investments are complements (normally, education would disappear from a standard first-differenced wage growth regression). Optimal investment equation (1) specifies that returns to

[5] For a more detailed description of the SCF data, see Avery and Elliehausen (1986). In cleaning up the raw data, the Federal Reserve filled in some missing values with predicted values: no such data were used herein for the income, asset, or risk-aversion variables (though some very unusual forms of wealth, such as the value of a personal business, were set to zero when missing).

[6] I construct the wage variable by using the responses to the question, "How much do you currently earn before taxes on your main job? (Is that per hour, week, month, or what?)" The majority of the responses are hourly, weekly, or monthly. It is noteworthy that when the results below are duplicated for income growth, they are very similar, producing slightly weaker tenure returns and stronger experience returns.

[7] Note that DTEN2 has a large variance: for workers with 3 years of tenure in 1986, DTEN2 = 9; for workers with 20 years of tenure, DTEN2 = 111; and for workers who quit high-tenure jobs, DTEN is very negative.

investment decline as retirement approaches; DTEN2 and DEXP2 capture this trend.[8] Given this **X** vector, individual differences in risk aversion $R$ will capture individual differences in unobserved quantities of investment relative to those predicted by vector **X.** Variable definitions and statistics are presented in appendix table B1.

The model developed in Section II suggests that risk-averse workers are less likely to make investments that have a high variance of returns, such as investing in risky firm-specific or occupational skills. These relationships translate into the empirical hypothesis that more risk-averse workers have lower growth rates of wages.

Two measures of risk aversion are developed from the data set used here. The first, called ASSET, is the proxy for $\alpha$, the share of financial wealth placed in risky assets used in equation (7). It is defined as ASSET $\equiv$ (STOCKS + BONDS + MUTUAL FUNDS)/(NET WORTH), adjusted for income tax rates.[9] Assuming that individuals possess a single concave utility function, so that inferences can be made about their degree of risk aversion from their behavior in allocating financial wealth, ASSET is an appropriate measure of risk aversion.

However, there are several reasons why the ASSET variable may be a weak indicator for risk aversion, despite its theoretical importance. The most obvious reason is that many families may have such low levels of financial net worth that they put none of it in risky assets. In the SCF, 1,072 of 2,199 families held no risky assets, creating an uninformative mass point at ASSET = 0. These same families may have sufficient human capital wealth to wish to make risky human capital allocations. Second, transactions costs may inhibit families from investing in risky assets, though the ease of purchasing all types of mutual funds suggests that transactions costs need not be a deterrent nowadays. Third, families with equal values of ASSET may have very different degrees of risk aversion, since the composition of stocks and bonds in the risky portfolio can vary widely.[10]

[8] The model of app. A specifies a rising $\eta$ in eq. (1): as $t$ approaches $T$, the marginal rate of substitution between financial wealth and human capital (i.e., $\eta$) rises because the capacity to produce future labor income falls, therefore reducing the impact of current human capital on future financial wealth, $1/\eta$ (Williams 1979, p. 534).

[9] The assets in NETW that are generally classified as "risk-free" are equity in the home, checking and savings accounts, and savings bonds and life insurance (Friend and Blume 1975). The model of Sec. II disregards taxes, but, as developed by Friend and Blume (1975), the asset variable should be $\alpha(1 - t)$, where the average tax rate $t$ is calculated by applying 1982 federal tax rates to the taxable income reported in the survey.

[10] The theoretical portfolio allocation model also implies that all investors hold the same market portfolio, though there is a lot of evidence that they do not. If,

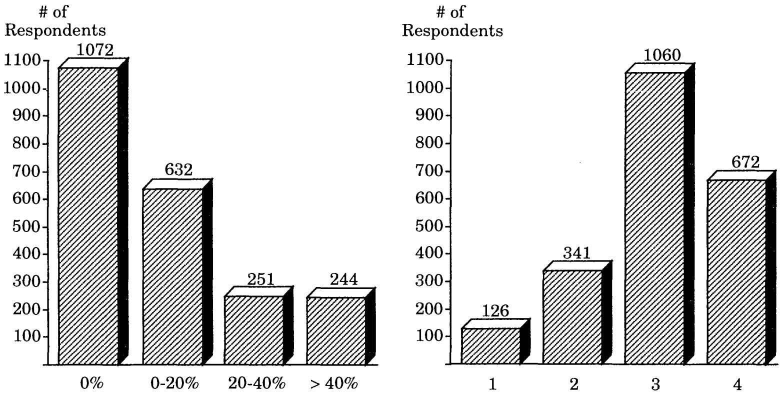


FIG. 1.—*Left panel,* ASSET distribution. The percentage of wealth placed in risky assets is shown. *Right panel,* RISK distribution. 1 = take substantial risks, 2 = take above-average risks, 3 = take average risks, and 4 = take no risks.

For these reasons, an alternative proxy for risk aversion available in the SCF data set is used here. For the variable called RISK, the SCF asked respondents in 1983 to describe themselves as having one of four attitudes toward financial risk: (1) 126 respondents said they "take substantial risk to earn substantial return;" (2) 341 said they "take above average risk to earn above average returns," (3) 1,060 said they "take average risk to earn average return;" and (4) 672 said they "take no financial risk." Because human capital is also an inherently "financial" risk, individual survey responses to the above question are likely to be relevant to the individual's desire to take risks in investing in human capital. Though economists typically avoid the use of survey questions that solicit opinions, this risk-attitude variable may be the best available proxy for an important variable. The issues of this variable's relevance and its interpretation will be discussed in greater depth below, following an examination of potential measurement error. The discrete frequency distributions for both variables, ASSET and RISK (ranging from 1 to 4 for the survey responses), are graphed in figure 1. They exhibit reasonable variance and have a simple correlation of −.10.

For the estimation of equation (7), the variable RISK is separated into two dummy variables: RISD3 is to take average risks (RISD3 = 1 for RISK = 3); RISD4 is to take no risks (RISD4 = 1 for RISK = 4); and the omitted dummy category is risk takers, RISK = 1 or 2 (there are too few observations in category 1 to separate these). Replacing $\alpha_i$ in equation

e.g., households with lower income hold portfolios with smaller market $\beta$ risk, then the ASSET variable will overstate risk.

**Table 1**
**Dependent Variable: Real Wage Growth Rate, 1983–86**

| | OLS* (1) | ASSET† (2) | RISK† (3) |
|---|---|---|---|
| ASSET | ... | 1.04 (2.39) | ... |
| RISD3 | ... | ... | −.465 (−4.37) |
| RISD4 | ... | ... | −.508 (−4.54) |
| DTENURE | .029 (5.33) | .032 (6.08) | .045 (5.08) |
| DTEN2 | −.0004 (−2.16) | −.0006 (−3.07) | −.0007 (−2.23) |
| DEXP2 | −.0007 (−4.81) | −.0007 (−3.49) | −.0007 (−4.79) |
| EDUC | .0089 (2.23) | .0071 (2.42) | .0068 (1.79) |
| $R^2$ | .0540 | .0559 | .0586 |
| $\sqrt{SSE/\Sigma z_i}$‡ | 22.40 | 22.25 | 22.05 |

NOTE.—*t*-statistics are in parentheses. Other variables included in the regressions are a constant term and UNION, MALE, BLACK. The latter three shift the intercept but they do not interact with RISK.
* Ordinary least squares (OLS) regression: $\Delta \ln w = \mathbf{XA}$ for coefficient vector $\mathbf{A}$.
† Nonlinear least squares: $\Delta \ln w = \mathbf{XA}\ (1 + bR)$, where the proxy for risk aversion $R$ is ASSET in col. 2 and RISK dumies in col. 3 and $R$ has coefficient $b$.
‡ These values are equal to $\sqrt{SSE/\Sigma z_i}$, where $\Sigma z_i$ is the sum of the weights, thus producing a statistic that is not inflated by weighting. SSE = sum of squared error.

(7) with dummy variables for risk aversion produces the function to be estimated,

$$\Delta \ln w_i = (1 + b_1 \mathrm{RISD3}_i + c_1 b_2 \mathrm{RISD4}_i)\mathbf{X}_i\mathbf{A} + e_i, \tag{8}$$

where the 1 is the omitted dummy category of risk takers and $\sigma_b^2$ is assumed to be fixed across investors (this assumption is relaxed below in Sec. IIIC).

Column 1 of table 1 displays the standard results for the wage growth equation when risk aversion is assumed to be constant across individuals. The regression coefficients have the usual signs.[11] The results in columns 2 and 3 introduce heterogeneity in risk aversion by estimating equations (7) and (8). The coefficients for both risk aversion proxies, on ASSET in column 2 and on the RISK dummies in column 3, are statistically significant and are consistent with the hypothesis that individuals who are risk takers achieve higher rates of income growth due to greater unobserved

[11] Sex and race also enter the wage growth equation but are always insignificant, so their coefficients are not displayed in the tables. Union coverage has a significant negative effect on wage growth, though it is not displayed. Given the weak effects of these variables, they are not included in the interaction vector **X** (and unconstrained interactions with RISK are insignificant). A constant term enters **X**, representing DEXPER, which is constant across individuals.

**Table 2**
**Empirical Magnitude of the Effect of Risk Aversion on Predicted Wage Growth**

| (1) | | (2) | |
|---|---|---|---|
| RISK | $\Delta\ln w$ | ASSET | $\Delta\ln w$ |
| 1, 2 | .108 | 0 | .062 |
| 3 | .059 | .1 | .066 |
| 4 | .052 | .4 | .078 |

investments in human capital.[12] As anticipated, ASSET is less significant than RISK, possibly because of its uninformative mass point at zero.

To assess the empirical magnitude of the effect of risk aversion on wage growth, predicted wage growth rates are calculated in table 2 for increasing levels of RISK and ASSET, with all other variables set to mean values. An investor willing to take above-average risks has an expected 3-year real growth rate of 10.8%, compared with the wage growth rate of 5.2% for the highly risk-averse investor. The results using the ASSET variable have a comparable effect—an investor placing 40% of the family's financial wealth in risky assets expects a wage growth rate of 7.8%, compared with the 6.6% average. As these growth rates compound over time, they can produce significant differences in income levels.

It is possible that the observed negative correlation between wage growth and risk aversion is spurious. If wage growth is correlated with high *levels* of wealth and wealthy people are risk takers, then the effect of risk aversion on wage growth would reflect a wage-wealth correlation, not a causal effect of risk aversion on risk taking and wages. To test for this spurious correlation, net worth is added to the risk-aversion vector in the wage growth regression: the risk-aversion coefficients are unchanged, and an $F$-test rejects the inclusion of net worth ($F(1; 2{,}198) = .58$). Net worth is also insignificant in the more complicated functional forms developed below. The apparent reason for the insignificance of wealth is that wealthier people are older, and income growth falls with age. There are no age patterns in the risk-aversion measures, and the effect of net worth on risk aversion is quantitatively small.[13] Hence it appears

[12] The $F$-test for the null hypothesis that risk aversion is homogeneous is $F(2; 2{,}190) = 5.63$ for RISK dummies and $F(1; 2{,}191) = 4.66$ for ASSET. The functional form of the equation containing ASSET is $\Delta\ln w = (1 + b\cdot\text{ASSET})\text{XA} + \text{e}$, where coefficient $b$ is presented in col. 2. The more restrictive functional form of eq. (7), $\Delta\ln w = (b\cdot\text{ASSET})\text{XA} + e$, is rejected by the data.

[13] Regression and logit results in which ASSET and RISK are regressed on linear and quadratic age, education, net worth, and human capital wealth are available from the author. Models of risk aversion analogous to those of Friend and Blume (1975) were estimated. One wealth effect may arise from the presence

that the negative correlation between wage growth and risk aversion found in the estimation of equation (8) is not spurious.

### C. Alternative Wage Growth Equations

Two restrictions that were placed on the estimation of wage growth equation (8) in table 1 are now relaxed in this section: first, the variance of human capital investment returns, $\sigma_b^2$, is permitted to vary across individuals, and second, the returns to risk taking are permitted to vary across different types of human capital investments. We begin with the latter issue.

*Introducing Different Types of Human Capital Investment.*—The above model, $\Delta\ln w = (1 + b'\tilde{R})\mathbf{XA}$, restricts the risk-aversion dummies, $\tilde{R}$, to interact with the total returns to investment **XA** as one unit. A less restrictive model lets $\tilde{R}$ interact separately with each element of wage growth, $a_j x_j$ from **XA**, to isolate the different ways in which risk aversion may reduce wage growth: $\Delta\ln w = \mathbf{XA} + \text{RISD3}(b_1 a_1 x_1 + \ldots + b_k a_k x_k) + \text{RISD4}(c_1 a_1 x_1 + \ldots + c_k a_k x_k)$, where $x_1, \ldots, x_k$ are the elements of **X**. Columns 1a–1c of table 3 present the estimates of the three coefficient vectors $a$, $b$, and $c$.[14] The coefficients in columns 1b and 1c are the percent decline in returns due to increasing risk aversion. For example, the $b$ coefficient on DTENURE implies that the return to tenure is 50.13% lower for average risk takers than above-average risk takers (holding constant DTEN2). Pronounced risk aversion (RISD4 = 1) lowers the estimated returns to tenure, to experience, and to education by 25%–92% relative to risk takers' returns.[15]

The regression results thus far also restrict the residual variance to be homoscedastic, though equation (7) indicates that the residuals may ex-

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of a spouse's income: married men may be greater risk takers if their wives work. This notion is the focus of Shaw (1987).

[14] Models were also estimated in which ASSET interacted with each $a_1 x_1$, but these interactions were less significant than those with RISK, consistent with the poorer quality of the ASSET variable. A more restricted model was also estimated, in which $\Delta\ln W = XA + \text{RISD3}(ba_1X_1 + \ldots + ba_kX_k) + \text{RISD4}(ca_1X_1 + \ldots + ca_kX_k)$, but these restrictions were rejected relative to the unrestricted version in the text.

[15] The estimates in table 3 should contain a constant term in **X** that is interacted with the RISK dummies, because DEXPER becomes a constant in the **X** vector. When RISK · EDUC interactions are also introduced, the constant · RISK interactions become insignificant, implying that each educational level has a different constant term that interacts with RISK (or, equivalently, that the return to DEXPER varies by EDUC and RISK). Thus, the estimates contain a constant term but no constant · RISK interactions. Since EDUC · RISK interactions represent EDUC · DEXPER · RISK interactions (because DEXPER = 3 for all individuals), the equation should also contain EDUC · DEXP² · RISK interactions. These higher-order interactions are insignificantly different from zero.

**Table 3**
**Dependent Variable: Real Wage Growth Rate, 1983–86**

| | Overall (1) | | | Subsample of Stayers (2) | | |
|---|---|---|---|---|---|---|
| | (a) | (b) | (c) | (a) | (b) | (c) |
| EDUC | .0127 (2.76) | −.336 (−1.80) | −.245 (−1.39) | .0189 (3.81) | −.477 (−2.81) | −.548 (−2.61) |
| DTENURE | .0600 (5.45) | −.5013 (−3.27) | −.8262 (−5.81) | . . . | . . . | . . . |
| DTEN2 | −.0011 (−2.44) | −.469 (−1.42) | −.927 (−2.05) | −.0016 (−3.71) | −.937 (−2.73) | −.808 (−1.88) |
| DEXP2 | −.0012 (−4.28) | −.565 (−2.74) | −.479 (−2.05) | −.0008 (−3.98) | −.162 (−0.51) | −.629 (−1.88) |
| $R^2$ | | .0646 | | | .0840 | |
| $\sqrt{SSE/\Sigma z_i}$* | | 21.91 | | | 21.86 | |

NOTE.—$t$-statistics are in parentheses. Other variables included in the regressions are UNION, MALE, BLACK, and a constant. Nonlinear least squares: $\Delta \ln W = \mathbf{XA} + \text{RISD3}\,(b_1 a_1 x_1 + \ldots + b_k a_k x_k) + \text{RISD4}\,(c_1 a_1 x_1 + \ldots + c_k a_k x_k)$, where cols. a, b, and c contain the $a$, $b$, and $c$, coefficient vectors, respectively.

* These values are equal to $\sqrt{SSE/\Sigma z_i}$, where $\Sigma z_i$ is the sum of the weights, thus producing a statistic that is not inflated by weighting. SSE = sum of squared error.

hibit heteroscedasticity. The test for heteroscedasticity for this nonlinear model is to regress the predicted residuals on all nonredundant cross-products of the gradient vector $\partial f(X, \hat{\beta})/\partial\beta$ where $y = f(X, \beta) + e$. The resulting $NR^2$ is distributed as $\chi^2$ (White and Domowitz 1984). The results (based on table 3, col. 1) indicate acceptance of the null hypothesis of no heteroscedasticity at the 5% level. Heteroscedasticity is also rejected in its more restrictive form underlying equation (7)—that the residual variance is a function of risk-aversion dummies—even though footnote 22 shows some evidence of differences in the $\sigma_e^2$ by risk category. Apparently, the differences are too small to be significant.[16]

What do the regression results of table 3 tell us about the mechanisms by which risk takers achieve faster wage growth rates? Risk takers who earn higher returns to general skills, as represented by education and general experience, may be investing more in risky occupational skills or general unobserved skills (such as managerial expertise). Similarly, risk takers who earn greater returns to tenure are investing in more unobserved risky employer-specific skills than the tenure variable alone would imply. Across all types of investments, the econometrician cannot observe the riskiness of the investments or the intensity of investment in risky skills. For one individual, occupational investment may be the riskiest investment, whereas for another individual, firm-specific investment may be especially risky.[17] The econometrician simply observes that risk takers are earning greater wage returns to all types of human capital investments, and these higher rates of wage growth are likely to arise from greater unobserved risky investing.

The theoretical model of appendix A, and the interpretation of the results presented thus far, emphasize the riskiness of time-consuming investments on the job—omitted from these discussions is the effects of

[16] Note that the regression results and heteroscedasticity tests produce the same conclusions with unweighted data. Note also that the empirical model is also reestimated as seemingly unrelated regressions, with eqq. (7) and (2) estimated jointly under the hypothesis that they may face correlated shocks, but the correlation is found to be insignificant at .017.

[17] Given only the observed EXPER and TENURE, it is impossible to say whether general or firm-specific skills are riskier or, e.g., whether risk-averse workers are more likely or less likely to quit their jobs. They will be more likely if they are investing in general occupational skills that are readily transferred. They will be less likely to quit if investing in firm-specific skills is viewed as less risky than the uncertainty of a new job match. The *intensity* of investing in occupation-specific or firm-specific skills is unobserved (Shaw 1984; Topel 1991): many workers with long tenure may be unskilled and simply fear the riskiness of job mobility. Thus, testable hypotheses regarding the riskiness of general and firm-specific skills are lacking. On average, general investments should be less risky, but the econometrician cannot readily separate these from risky specific investments in occupations or industries.

risky job changes, such as occupational change or employer change. Yet, the empirical results contain the wage effects of such changes. For example, more-educated workers may have a higher return to risk taking because they are more likely to seek risky promotions. The tenure variable especially confounds two very different forms of risky decision: investing in firm-specific skills and changing jobs. To focus only on on-the-job investments, the model is reestimated for the subsample of stayers, thereby eliminating the variability in tenure arising from quits and layoffs. Among stayers (table 3), the return to education falls a significant 55% for highly risk-averse workers relative to risk takers. The separate effects of firm-specific and general experience are identified through the squared terms, DTEN2 and DEXP2, which do show differential returns to risk taking.[18]

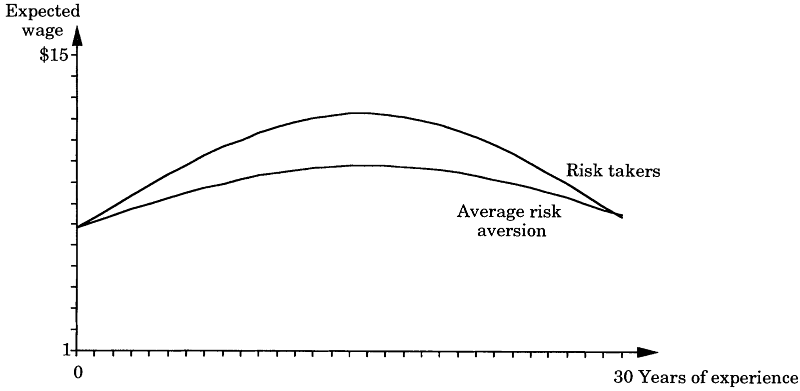
The magnitudes of the gains to risk taking are displayed in figure 2, which plots the predicted wage profiles for the "stayers" results of table 3 (plots for "movers" require predicting job changes and produce similar profiles to those of stayers). The figure takes the predicted wage growth rates for a white male nonunion worker (with initial growth intercept .0183) from table 3[19] and applies them to entry-level wages of $6.84 per hour for a high-school-educated and $9.83 for a college-educated white male nonunion worker (entry wages are obtained from a 1983 wage level regression).

The average gains to risk taking displayed in figure 2 are clearly substantial, most notably for college-educated workers.[20] Moreover, the results

[18] The decline in the investment intensity with experience and tenure is identified by the DTEN2 and DEXP2 terms, but unless one assumes a different parametric form for the intensity decline, the effect of both DTENURE and DEXPER falls into the constant term. Interactions between the constant and the risk dummies are insignificant after controlling for the education-risk interactions—when these education-risk interactions are omitted, the risk dummies are very significant (coefficients [and *t*-statistics] for RISD3 and RISD4 are −.893[−5.04] and −.987[−5.33]). The education-risk interactions simply imply that the returns to tenure and experience differ by educational level. These educational differences will be the focus of Sec. IV.

[19] The predicted growth rates are divided by three, to produce real annual growth rates from the 1983–86 growth rates.

[20] The results presented thus far clearly suggest that risk takers earn higher returns to investment in education and on-the-job training, but the point estimates should be viewed as approximations. The parametric functional form of the wage equation imposes a quadratic age-earnings profile, despite evidence elsewhere rejecting the quadratic form (Murphy and Welch 1990). Moreover, though the coefficients on the RISK interactions are generally statistically significant, their confidence intervals are wide: wage growth is a notoriously difficult variable to explain. The results that risk takers have higher wage growth rates is robust, but the sources of the increase are not readily disentangled, and the curvature of the growth path is an approximation.



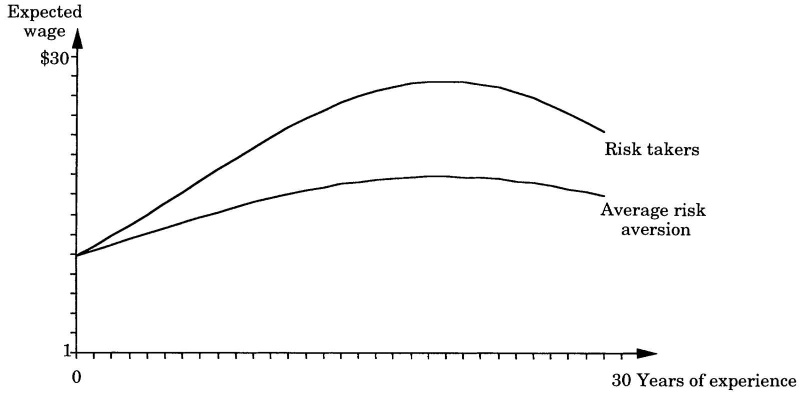




FIG. 2.—Magnitudes of gains to risk taking for high-school-educated workers (*above*) and college-educated workers (*below*).

in the figure probably underestimate returns, because the wage levels at market entry are likely to be higher for risk takers, further increasing the gap in lifetime income differences. While wage level equations are not the focus of this article, they are interesting for the corroborative evidence they provide.[21] RISK and ASSET effects in the log (wage) equations are sizable. In a standard log (wage) regression the coefficients ($t$-statistics) are −.294 (−4.94) RISD3 and −.402 (−5.23) RISD4; and in a separate regression, .613 (8.93) for ASSET. They imply that for the average worker,

[21] The equations are especially susceptible to the concern that risk takers may have higher income levels because they are wealthier (and there is a clear wealth-income correlation). However, when net worth is added to the wage level equations it is significant, but it only modestly dampens the significance of the risk-aversion variables.

a risk taker earns 23% more than a risk averter, all else being equal, and these results are very robust to variation in functional form.

*Introducing Heterogeneity in the Variance of Returns to Investment.*—The final step in assessing the effect of risk aversion on wage growth is to incorporate information on the variance of the returns to investment in human capital, $\sigma_h^2$, in the estimation of equation (8).[22] Equation (8) is derived from equation (1), which implies that the effect of risk-averse preferences, *R,* should be weighted by the riskiness of the human capital investment, $\sigma_h^2$, because as $\sigma_h^2$ rises, risk-averse workers will invest less in unobserved risky investments, *s*. So observed wage growth should fall when $\sigma_h^2$ rises, because unobserved investment *s* is smaller.

The data set provides several potential indicators of the riskiness of investment that are now included in the estimated version of equation (8) presented in table 4. The potential for undertaking risky human capital investments is likely to be smaller at unionized firms, at government jobs, and at large firms (if monitoring individual effort is more difficult) (Brown and Medoff 1989). When we look only at job stayers (so there are no changes in job status), there is no apparent difference for union versus nonunion workers (not shown), but risk takers in small firms (employees $< 100$) and in the private sector have the highest returns to risk taking, as represented by sectoral differences in the RISK-EDUC interactions.[23]

## IV. Interpretation of Results

A closer examination of the risk-aversion variable is needed to assess the qualitative and quantitative implications of the conclusion that risk-

[22] In the analysis thus far, one implication of the model of the investment in risky assets has not been tested in the empirical work—the empirical prediction that the income of all risk takers should have a higher variance. The variance of returns is defined for empirical purposes as the variance of wage growth after controlling for all observed determinants of wage growth. This measure of the riskiness of investments is clearly flawed—all unobserved factors that are known to the individual as determinants of wage growth will be deemed riskiness of return. By and large, risk takers face a higher variance of income, accompanied by the higher returns to investment estimated above. Nevertheless, it is instructive to see how strongly correlated risk aversion and the variance of wages are:

| RISK | Variance of Residual Wage Growth | Variance of Residual Income Level |
|---|---|---|
| 1 | .524 | 105,599 |
| 2 | .505 | 117,134 |
| 3 | .493 | 47,334 |
| 4 | .477 | 33,292 |

[23] The RISK-EDUC interactions merely imply that the RISK intercept varies by educational level. The cell sizes for public sector workers ($N = 364$) and small-firm workers ($N = 430$) are fairly small, and the *F*-statistics can only weakly differentiate the private-public difference ($F(3; 1{,}636) = 2.19$) and the large-small difference ($F(3; 1{,}636) = 2.27$) in the risk-related returns to education.

Table 4
Dependent Variable: Real Wage Growth Rate, 1983–86

| | 1 | | | 2 | | |
|---|---|---|---|---|---|---|
| | (a) | (b) | (c) | (a) | (b) | (c) |
| EDUC·PRIVATE | .0192 (3.51) | −.563 (−2.95) | −.642 (−2.71) | . . . | . . . | . . . |
| EDUC·PUBLIC | .0162 (1.64) | −.193 (−.67) | −.223 (−.63) | . . . | . . . | . . . |
| EDUC·LARGE | . . . | . . . | . . . | .0182 (3.31) | −.465 (−2.59) | −.455 (−2.06) |
| EDUC·SMALL | . . . | . . . | . . . | .0179 (1.85) | −.622 (−1.73) | −.914 (−1.68) |
| $R^2$ | | .085 | | | .085 | |
| $\sqrt{SSE/\Sigma z_i}$* | | 21.79 | | | 21.80 | |

NOTE.—$t$-statistics are in parentheses. The model that is estimated is the same as that in col. 2 of table 3, except that the returns to education are permitted to vary by employer type. All other variables, whose coefficients are not displayed, are the same as those in table 3. LARGE refers to large firms vs. SMALL; PRIVATE refers to private-sector firms vs. PUBLIC.

* These values are equal to $\sqrt{SSE/\Sigma z_i}$ where $\Sigma z_i$ is the sum of the weights, thus producing a statistic that is not inflated by weighting. SSE = sum of squared error.

Table 5
Distribution of Risk

| | No. of Responses | |
|---|---|---|
| RISK* | EDUC ≤ 12 | EDUC > 12 |
| 1 | 56 | 70 |
| 2 | 98 | 243 |
| 3 | 454 | 606 |
| 4 | 438 | 234 |

* 1 = least averse, and 4 = most averse.

averse workers have lower wage growth rates. As a proxy for true risk aversion (if such a variable exists), RISK is likely to measure risk aversion with error.[24]

One can form priors on the nature of the measurement error. More-educated individuals may be better able to understand the concept of financial risk in answering the survey question. The distribution of RISK certainly varies with education (as displayed in table 5), suggesting that the RISK-education relationship should be explored.

The wage growth regression results presented above have shown that the return to risk taking is greater for more-educated workers, and these results are reinforced when wage growth equations are estimated separately for educational subgroups in table 6. Risk aversion has a far more negative impact on wage growth for more-educated workers. When the sample is constrained to job stayers, the returns to education rise for risk takers in the less educated subsample,[25] but there is essentially no difference between the stayer and the mover results among the college educated (not shown). The more significant effect of risk taking for more-educated workers could result from either less measurement error in the RISK variable or from

[24] The standard practice for reducing coefficient bias resulting from measurement error is to instrument RISK with variables that are correlated with true risk aversion, but uncorrelated with the measurement error (Griliches 1974). However, I am not aware of any such variables for RISK. Another factor that could introduce coefficient bias is endogeneity of RISK. RISK could be endogenous if people become wealthy from high rates of past income growth that are correlated with current high income growth. However, this hypothesis is refuted in Sec. III. This article purposely focuses on wage changes rather than levels to avoid this endogeneity problem, and thus a recursive model seems appropriate.

[25] For the less-educated stayers, estimates comparable to the bottom row of cols. 2a, 2b, and 2c of table 6 produce the following coefficients ($t$-statistics): .048(3.91), −.211(−1.54), and −.253(−1.79).

**Table 6**
**Educational Differences in Wage Growth Rates**

| | EDUC ≤ 12 | | | | EDUC > 12 | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2† | | | | 4† | | |
| | 1* | (a) | (b) | (c) | 3* | (a) | (b) | (c) |
| RISD3 | −.191 (−1.18) | ... | ... | ... | −.753 (−10.38) | ... | −.421 (−3.74) | ... |
| RISD4 | .011 (.07) | ... | ... | ... | −.768 (−7.84) | ... | ... | −.533 (−4.22) |
| DTENURE | .017 (2.14) | .027 (1.53) | .025 (.03) | −.637 (−1.42) | .079 (5.82) | .087 (6.25) | −.610 (−4.92) | −.747 (−4.40) |
| DTEN2 | −.0001 (−.29) | −.0005 (−.18) | .701 (.31) | −.408 (−.40) | −.0013 (−2.69) | −.0013 (−4.00) | −.515 (−1.37) | −.444 (−.65) |
| DEXP2 | −.0012 (−3.70) | −.0013 (−2.56) | −.426 (−1.39) | −.451 (−1.38) | −.0014 (−2.81) | −.0012 (−1.78) | −.782 (−3.54) | −.866 (−2.92) |
| EDUC | .018 (2.09) | .023 (2.32) | −.326 (−1.28) | −.115 (−.61) | .0082 (1.50) | ... | ... | ... |
| $n$ | 1,046 | | 1,046 | | 1,153 | | 1,153 | |
| $R^2$ | .0583 | | .0714 | | .08640 | | .110 | |
| $\sqrt{SSE/\Sigma z_i}$‡ | 7,739,411 | | 7,672,888 | | 6,774,003 | | 6,565,576 | |

NOTE.—$t$-statistics are in parentheses. Also included in the regressions are UNION, MALE, BLACK, and a constant. Note that among the college educated there are too few education levels to interact education and RISK, so RISK enters linearly in model 4.

* Nonlinear least squares: $\Delta \ln w = \mathbf{XA}(1 + b\tilde{R})$, where the proxy for risk aversion $R$ has coefficient $b$.

† Nonlinear least squares: $\Delta \ln w = \mathbf{XA} + \text{RISD3}\,(b_0 a_0 + b_1 a_1 x_1 + \ldots + b_k a_k x_k) + \text{RISD4}\,(c_0 a_0 + c_1 a_1 x_1 + \ldots + c_k a_k x_k)$.

‡ These values are equal to $\sqrt{SSE/\Sigma z_i}$, where $\Sigma z_i$ is the sum of the weights, thus producing a statistic that is not inflated by weighting.

**Table 7**
**Age Differences in the RISK-DTENURE Return**

| | AGE < 40 ($N$ = 1,114) | | | AGE ≥ 40 ($N$ = 1,113) | | |
|---|---|---|---|---|---|---|
| | | Risk Interaction | | | Risk Interaction | |
| | | RISD3 | RISD4 | | RISD3 | RISD4 |
| | (a) | (b) | (c) | (a) | (b) | (c) |
| DTENURE | .042 (2.01) | −.275 (−.59) | −.854 (−2.67) | .074 (4.83) | −.564 (−3.88) | −.715 (−4.11) |
| DTEN2 | −.0011 (−.81) | −.944 (.38) | −1.03 (−1.24) | −.0015 (−2.91) | −.675 (−2.92) | −.847 (−3.28) |

NOTE.—$t$-statistics are in parentheses. The rest of the model specification is the same as that in table 3, col. 1.

the greater opportunities for risky human capital investments that are available to more-educated workers, as discussed in Section III.[26]

These results produce some very interesting implications for the relationship between education and income growth. First, it was shown that more-educated workers are less risk averse.[27] Since risk takers have greater income growth, one source of returns to education may be a willingness to take risks on the job. Previous researchers have omitted this return, or in estimating the returns to education, have confounded them with returns to risk taking.[28] Second, *within* the highly educated group—those with a college education—risk taking really pays off with higher wage growth (as shown in table 6). It is not that surprising that risk preferences have more impact for college-educated workers—the types of jobs they hold are more likely to reward or to provide opportunities for investments.

The correlation between education and risk taking suggests that one characteristic of risk taking, as it is measured in this paper, is the ability to use information effectively.[29] In other words, risk taking is in part an ability to comprehend uncertain outcomes and to make intelligent decisions regarding them. This ability pays off in labor markets (with higher income growth), as well as in financial markets. Of course, because education explains only a small proportion of the variance of risk taking, the majority of the wage effects of risk taking are associated with interpersonal differences in tastes that are unexplained by education: within the college-educated group, risk takers earn more.

## V. Conclusion

The objective of this paper is to estimate a model of the joint investment in risky human capital and risky financial assets, using the information contained in the risky financial decisions to make inferences about indi-

[26] Note that the wage growth rates of older workers could also be more sensitive to risk aversion, again reflecting either reduced measurement error or an increase in $\sigma_h^2$ with age. The age differences in the RISK-DTENURE return are shown in table 7. The variance of returns $\sigma_h^2$ could be higher for younger people who are unsure of their own productivity and have more opportunities for investing.

[27] In regression and multilogit results (available from the author), risk aversion falls significantly with education even after controlling for financial and human wealth effects on risk aversion.

[28] The evidence that risk taking has such a beneficial effect in small firms also suggests that education has a valid economic effect, by raising productivity, rather than merely sorting workers into the primary sector of the dual labor market. However, it is not possible to assess whether education acts as a screening device for risk takers or teaches people to take risks.

[29] The negative correlation between risk aversion and education may also reflect a low rate of time preference for the more educated and for risk takers.

vidual heterogeneity in risk aversion. The theory suggests that human capital investment, and thus income growth, should decline with risk aversion and with the variance of returns to the investment.

When we use the SCF for 1983–86, the empirical results imply that risk aversion significantly lowers wage growth. Risk-averse workers have lower returns to education, to general experience, and to tenure. They appear to be less likely to undertake risky postschool investments. Furthermore, assuming that the variance of returns to investing rises with education, with firm size, and with private sector employment, income growth for risk takers rises with the variance, as suggested by the theory.

Though the estimated effects of risk aversion appear to be sizable, risk aversion remains (and is likely to forever remain) a nebulous concept. An analysis of the relationship between risk aversion, as it is measured here, and education clarifies the concept. Whether risk aversion is measured from information on the allocation of wealth to risky financial assets or from a survey question about that desired allocation, it clearly decreases with education. This implies that previous estimates of the returns to education may well be including returns to one's willingness to take risks. Alternatively, risk taking, in financial and job markets, may to some degree reflect an individual's willingness and ability to utilize information effectively in making decisions under uncertainty (which education may screen for or teach). On the other hand, measured risk aversion also captures differences in tastes that are uncorrelated with education: tastes for risk vary substantially within the college-educated sample, and the empirical results suggest that the returns to human capital investments are much higher among college-educated workers who are risk takers.

There are a number of reasons why these results should be of interest to economists and policymakers. Economists have long posited models in which risk aversion plays a key role, and the rise of structural models of behavior under uncertainty emphasizes its importance. The standard practice of estimating a parameter value for the degree of constant relative risk aversion may omit important sources of heterogeneity that are not orthogonal to other observed variables (this is clearly true for education). More generally, and of interest to policymakers, the importance of risk aversion has very clear implications for income distribution. This article supports the conclusion that risk aversion and income are positively correlated, so that the variance of risk aversion contributes to the variance of the distribution of income. And last, but most important, the finding that risk aversion lowers the investment in human capital has very definite implications for economic growth. Economic growth is maximized when resources are allocated to uses that maximize their productivity. Risk aversion alters that allocation by favoring uses that are less risky—so workers are less likely to invest in specialized skills, or to change jobs or to work under incentive contracts. These decisions lower the productivity of the workforce. Yet, if risk aversion is in small part associated with a lack of information, or an inability to use information effectively (thus creating a fear of uncertainty), it can in part be reduced through education and training. Education would thus affect productivity not only directly, but also indirectly, by increasing individuals' willingness to take risks.

## Appendix A

## Derivation of Optimal Investment

The continuous-time model of Merton (1971) is augmented with the addition of human capital investment as an extension of the general model of Williams (1979). As is standard in human capital investment models, define $s(t)$ to be the share of initial human capital, $K(t)$, allocated to producing new human capital (in lieu of income) at time $t$, so that the growth of human capital is

$$K(t + \Delta t) = \frac{\omega(t + \Delta t)}{\omega(t)} [1 + h(t + \Delta t)s(t)]K(t) , \tag{A1}$$

where $h(t + \Delta t)$ is the individual's stochastic return to investment at time $(t + \Delta t)$ for investments made at time $t$.[30] This stochastic return to investment represents individual uncertainty about personal ability and firm-specific success that is nondiversifiable and noninsurable. The stochastic market return, $\omega(t + \Delta t)$, represents demand factors, such as industry or cyclical fluctuations. It is assumed that the two are uncorrelated. A correlation would exist if more stable demand conditions improved the prospects for individual promotions, but this is likely to be a weak covariance and is certainly unobserved by the econometrician.[31] By assumption, the current wage is certain while future wages are stochastic.

Assume that the stochastic parameters $h$ and $\omega$ are distributed lognormal, consistent with the widespread empirical evidence that wages are

[30] A linear production function is feasible in modeling investment under uncertainty (see Williams 1979).

[31] If these covariances were nonzero, the financial portfolio could be used to diversify the allocation of total wealth. For example, an individual working for IBM would buy Apple stock. But assuming that one cannot use human capital as collateral for investment loans, one would have to have financial wealth to diversify in this manner. This diversification should produce a financial wealth effect in the investment equation—wealthier people could diversify more, so they would invest more in human capital. But after controlling for education and risk aversion, no additional wealth effect is found below in the empirical results. As a practical matter, the covariances weighting the wealth effect cannot be reasonably calculated. See also the discussion of Liberman (1980), below.

distributed lognormal. The instantaneous growth equation for human capital is

$$\dot{K} \equiv \frac{dK}{K} = (\mu_\omega + \mu_h s)dt + (\delta_\omega + \delta_h s)' dZ \,, \tag{A2}$$

derived by expanding the distributions around $\Delta t$, substituting in equation (A1) and taking the limit $\Delta t \to 0$, and noting that $dZ$ is the instantaneous increment of a standardized Weiner process with coefficient $\delta$ (where $\Delta Z(t)$ is the random vector with means 0 and variance $\Delta t$ in the log normal distributions), $\mu_h$ and $\mu_\omega$ are the expected value of $h$ and $\omega$, and $\sigma_h^2 = \delta_h' \delta_h$, $\sigma_\omega^2 = \delta_\omega' \delta_\omega$.

Assume that the worker maximizes a time-separable expected utility function

$$\max E\left\{\int_0^T U[C(t), L(t), K(t)]\, dt + B(W(T))\right\} \tag{A3}$$

for consumption function $C(t)$, leisure $L(t)$, and bequest function $B$ that is concave in terminal wealth $W(T)$. Individual utility functions are also continuously differentiable, strictly increasing, and strictly concave. The financial wealth constraint is from Merton (1971):

$$dW = [(rW + y - C) + W(\mu - r1)'\alpha]dt + \alpha\sigma_f W dZ \,, \tag{A4}$$

where $W$ is current financial net worth, $y$ is current labor income, $\alpha$ is the proportion of current financial wealth allocated to risky assets, $\mu$ is the expected return on the risky asset portfolio, $r$ is the risk-free return, and $\sigma_f$ is the variance of the risky asset returns. The wealth constraint displays the ways in which human capital and financial capital differ: human capital is not marketable across alternative assets, and the individual cannot borrow against human capital to smooth his consumption over time. Nevertheless, the allocation decision for human wealth will be very similar to that of financial wealth: at each instant $t$ the individual decides to allocate a share of human wealth to producing current income and a share to the risky human capital investment.

Solving for optimal investments and assuming no corner solutions for investment $s(t)$, the optimal allocations to human and financial wealth are

$$s = \frac{\mu_h - \eta}{\sigma_h^2 R} \tag{A5}$$

and

$$\alpha = \frac{\mu - r}{\sigma_f^2 R} \,, \tag{A6}$$

where $\mu_h$ is the mean return to human capital investment and $\eta \equiv J_w/J_k$ is the marginal rate of substitution between financial wealth and human capital where $J(K, W, t)$ is the indirect utility function for the maximization of equation (A3), $R$ is the Pratt-Arrow index of constant relative risk aversion, $\sigma_f^2$ is the variance risky returns, and $(\mu - r1)$ is the standard vector of excess returns to investing in risky financial assets. Equation (A6) has been simplified by assuming that the covariance between financial and human wealth is zero, based on empirical evidence by Liberman (1980) that is reconfirmed here.[32]

## Appendix B

### Table B1
### Variable Means

| Variable | Mean | SD | Definition |
|---|---|---|---|
| DWAGE | .0678 | .493 | Real wage growth rate, 1983–86 $\equiv$ ln[WAGE$_{86}$/CPI] − ln WAGE$_{83}$ |
| RISK | 3.128 | .826 | Values of 1–4, with 4 being most risk averse (see text) |
| ASSET | .108 | .255 | The share of net wealth in risky assets $\equiv$ [(STOCK + BONDS + MUTUAL)/NETWORTH] |
| RISD3 | .47 | .49 | Dummy variable for RISK = 3 |
| RISD4 | .30 | .46 | Dummy variable for RISK = 4 |
| DTENURE | 1.647 | 4.079 | Change in tenure from 1983 to 1986 |
| DTEN2 | 38.125 | 103.877 | $(\text{TENURE}_{86})^2 - (\text{TENURE}_{83})^2$ |
| DEXPER | 2.956 | 1.228 | Change in experience from 1983 to 1986 |
| DEXP2 | 104.17 | 73.05 | $(\text{EXPER}_{86})^2 - (\text{EXPER}_{83})^2$ |
| EDUC | 12.946 | 2.627 | Years of education |
| AGE | 39.202 | 10.701 | Age in 1983 |

[32] Liberman (1980) estimates this covariance with a capital asset pricing model that contains covariances between returns on human capital and a marketable asset portfolio and finds the covariances to be so weak that he suggests that the two allocation problems should be treated separately. In order to calculate the systematic risk for human capital, a long time series of returns to investment is needed; thus Liberman uses average returns by aggregate industry, occupation, and educational attainment. It is quite possible that individual returns to investment do covary with market returns, but time-series data to assess the covariances are not available. I repeat the analysis using different data and more up-to-date time series. The most likely place for significant covariances is between industry asset returns and industry average personal income. I use industry stock portfolio returns from 1960 to 1985 for 17 industries, constructed by Fama and French (1988) (and kindly provided by Burton Hollifield). For personal earnings, I try to match these industries using Bureau of Labor Statistics (BLS) payroll data on weekly earnings by industry for 1960–85. Though I use more detailed industry returns than Liberman, I also find the covariances to be very weak. I also examine occupational earnings that are available from the BLS for accountants, buyers, chemists, and engineers. Covariances between these and the Standard and Poor's Index, the Wilshire 5000, and the real return on short and long Treasury bonds are again very weak.

**Table B1** (*Continued*)

| Variable | Mean | SD | Definition |
|---|---|---|---|
| UNION | .262 | .440 | Dummy variable for covered by a union |
| SMALL | .241 | .428 | Dummy variable for firm size < 100 employees |
| PUBLIC | .200 | .377 | Dummy = 1 if government employee (federal, state, local) |

## References

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