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EARNINGS DISPERSION, RISK AVERSION AND EDUCATION

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ABSTRACT

Earnings Dispersion, Risk Aversion and Education*

We estimate a dynamic programming model of schooling decisions in which the degree of risk aversion can be inferred from schooling decisions. In our model, individuals are heterogeneous with respect to school and market abilities but homogeneous with respect to the degree of risk aversion. We allow endogenous schooling attainments to affect the level of risk experienced in labour market earnings through wage dispersion and employment rate dispersion. We find a low degree of relative risk aversion (0.9282) and find that a counterfactual increase in risk aversion will increase schooling attainments. The estimates indicate that both wage and employment rate dispersions decrease significantly with schooling attainments.

JEL Classification: J20 and J30
Keywords: dynamic programming, earnings dispersion, human capital, returns to education and risk aversion

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1 Introduction

The acquisition of general human capital through education is one of the most important activities by which young individuals increase their potential lifetime earnings. While enrolled in school, individuals typically receive parental support and give up potential earnings in favor of higher future earnings. Parental transfers can take the form of housing services and other living expenses (such as food and transportation) and are typically unaffected by those random elements affecting household income. As opposed to parental transfers, which are most likely non-stochastic from the perspective of young individuals, future earnings are usually unknown. Both wages and unemployment rates are random variables that may vary over the life cycle and their distributions are potentially affected by human capital. Indeed, it is well known that schooling can reduce substantially the incidence of unemployment over the life cycle and can also increase lifetime earnings.

The effect of schooling on earnings dispersion (or wage and employment rate dispersion) is however more difficult to characterize. In stylized "implicit contract" frameworks, in which risk averse individuals are willing to trade wage rigidity against stable employment patterns, it is reasonable to assume that the need for risk sharing will be smaller for low educated workers who benefit from a relatively high level of social insurance. However, at the same time, wage dispersion may also vary with factors such as union status, occupation type and the like. As a consequence, the link between education and wage/earnings dispersion is not trivial.[1]

Modeling the level of risk involved in schooling decisions must however go beyond the effect of human capital on wages and employment and the difference in uncertainty between parental transfers and labor market wages. The possibility of interruption in the schooling accumulation process, due to various events such as health or personal problems, academic failure or other causes, can increase the risk associated to schooling as perceived by economic agents. This supplementary source of risk also needs to be taken into account in modeling schooling decisions.

Estimating the effect of schooling on wage dispersion and employment dispersion is a complicated task. As it stands now, there is no strong empirical evidence on the effect of education on wage/earnings dispersion. In the reduced-form literature devoted to the returns to schooling, the parameters of interest are often estimated from cross-section data. In such a framework, it is impossible to distinguish between unobserved individual ability and true wage dispersion and heteroskedasticity is usually ignored. Moreover, as schooling attainment is an endogenous variable, standard reduced-form techniques are ill-equipped to address wage heteroskedasticity. As a consequence, modeling schooling decisions and earnings dispersion in a context which allows for risk aversion requires the

[1] For a survey of the contract literature, see Rosen (1985).

use of structural stochastic dynamic programming techniques.

Although the estimation of structural dynamic programming of schooling decisions has become increasingly popular (Keane and Wolpin, 1997, Eckstein and Wolpin, 1999 and Belzil and Hansen, 2001, Sauer, 2001), very few economists have investigated schooling decisions in framework which allows for risk aversion or consumption smoothing.[2] Recently, Keane and Wolpin (2001), Sauer (2001) and Cameron and Taber (2001) have investigated the links between education financing and consumption smoothing and, more particularly, the effects of borrowing constraints on schooling decisions. All of them present evidence suggesting that borrowing constraints have virtually no impact on schooling attainments. Empirical results reported in Cameron and Heckman (1998) also suggest that borrowing constraints (and parental income) have virtually no impact on schooling decisions. However, as far as we know, the relationship between earnings dispersion (wage and employment rate volatility) and education has never been investigated.

Along with the subjective discount rate, the degree of risk aversion is one of the most fundamental preference parameters. For instance, knowledge of the degree of risk aversion can shed light on the welfare improvements of policies aimed at reducing income fluctuations over the business cycle. Until now, the empirical literature devoted to the measurement of the degree of risk aversion has been completely dominated by macroeconomists and financial economists. In financial economics, the degree of risk aversion and the discount rate are typically estimated in asset pricing frameworks using Euler equations. Usually, the estimates of the degree of risk aversion (within a power utility framework) range between 3 and 10 and represent a relatively mild degree of risk aversion. Indeed, these estimates are quite difficult to reconcile with actual data on long run average returns on risky and risk-free assets.[3] Strangely enough, labor economists have been completely absent of the debate. This is surprising. In virtually all western countries, labor income accounts for a much larger share of total income than does investment income and, until very recently, macroeconomic policies have been aimed at reducing variations in labor income.[4] As a consequence, measuring risk aversion from individual decisions affecting labor income appears a natural research agenda.

The main objectives of this paper are the following. First, it is to estimate the degree of risk aversion from a dynamic programming model of education

[2]In a standard recursive utility framework, such as the one used in this paper, there is a one-to-one correspondence betwen the degree of risk aversion and the willingness to smooth consumption (intertemporal substitution). Disentangling the behavior toward risk from the willingness to smooth consumption is beyond the scope of this paper.

[3]It is well known that, in order to solve the "Equity premium Puzzle", the degree of risk aversion would have to be enormous (certainly more than 50). For a review of the literature, see Kocherlakota (1996).

[4]In most western countries, labor income account for 60% to 70% of total income.

choices in which individual preferences are set in an expected (non-linear) utility framework. The model is based on the assumption that individual preferences are representable by an instantaneous power utility function and that individuals maximize the expected discounted value of lifetime utility over a fixed (known) finite horizon. Young individuals make optimal schooling decisions while taking into account that accumulated schooling affects both the first and the second moments of the lifetime distribution of earnings. As a consequence, the theoretical framework provides an opportunity to investigate both the degree of risk aversion and the rate of time preference as separate parameters[5]. The second objective is to evaluate how endogenous schooling attainments affect the variances of lifetime wages and employment rates and investigate how risk aversion affects schooling attainments. finally, our third objective is to evaluate how young individuals react to changes in the wage return to schooling, changes in school subsidies and changes in wage subsidies. Finally, we investigate how schooling attainments react to a counterfactual increase in wage and employment rate dispersion.

The model is implemented on a panel of young individuals taken from the National Longitudinal Survey of Youth (NLSY). We find that young individuals have a very low degree of risk aversion. The parameter estimate of the degree of relative risk aversion, 0.9282, is just somewhat below the degree of risk aversion consistent with logarithmic preferences. At the same time, our estimates of log wage and log employment rate regression functions indicate that, after conditioning on individual specific unobserved ability, wage dispersion and employment rate dispersion are highly heteroskedastic. More precisely, both wage and employment rate dispersions decrease with schooling. This is consistent with the hypothesis that risk sharing agreement are more common among highly educated (high wage) workers. Finally, we find that a counterfactual increase in the degree of risk aversion will increase schooling attainments. .

The content of this paper is as follows. Section 2 is devoted to the presentation of the model while the empirical specification is discussed in Section 3. Section 4 contains a brief description of the data. After a brief discussion of the structural parameter estimates and the goodness of fit (Section 5), the links between risk aversion, risk and schooling are investigated in Section 6. In Section 7, we present some elasticities of schooling attainments with respect to the return to schooling, school subsidies, wage subsidies and earnings risk. The Conclusion is in Section 8.

[5]We assume that individuals cannot borrow during school.

2 A Stochastic Dynamic Programming Model

The theoretical structure of the model is presented in Section 2.1 while the solution is discussed in Section 2.2.

2.1 Theoretical Structure

Individuals are initially endowed with family human capital, innate ability and preference parameters. Given their endowments, young individuals decide sequentially whether it is optimal or not to enter the labor market or continue accumulate human capital. The amount of schooling acquired by the beginning of date t is denoted S_t. When in school, individual receive income support, denoted ξ_t. The income support can be viewed as intergenerational transfers (or school subsidies). The net income is assumed to be non-stochastic. This reflects that parental transfers are most likely unaffected by those stochastic elements affecting household income. We assume that individuals interrupt schooling with exogenous probability $\zeta(S_t)$. The interruption state is meant to capture events such as illness, injury, travel or simply academic failure and may vary with grade level. In practice, it is difficult to distinguish between a real interruption and an academic failure as some individuals may spend a portion of the year in school and a residual portion out of school, as a result of a very high failure probability. When an interruption occurs, the stock of human capital remains constant over the period. The NLSY does not contain data on parental transfers and, in particular, does not allow a distinction in income received according to the interruption status. As a consequence, we ignore the distinction between income support at school and income support when school is interrupted.[6]

Each individual is endowed with an instantaneous (per period) power utility function. The expressions for the instantaneous utility of being in school,$U^s(.)$, is as follows:

$$U^s(\xi_t) = \frac{\xi_t^{1-\alpha} - 1}{1-\alpha} \tag{1}$$

Once the individual has entered the labor market, he no longer receives parental support but receives a wage rate w_t and an employment rate e_t. The total income flow, while employed, is given by $Z_t, = w_t \cdot e_t$. The instantaneous utility of entering the labor market, $U^w(.)$, is

$$U^w(Z_t) = \frac{Z_t^{1-\alpha} - 1}{1-\alpha} \text{ when in the labor market} \tag{2}$$

Individuals are risk averse (loving) when $\alpha > 0$ ($\alpha < 0$). Each individual maximize his expected discounted lifetime utility by choosing the optimal time to

[6]In the NLSY, we find that more than 82% of the sample has never experienced school interruption.

interrupt schooling and enter the labor market. The discount factor, β, is equal to$\frac{1}{1+\rho}$ where ρ is the subjective discount rate. The time horizon, T, is finite and is chosen to be when individuals turn 65 years old (a typical retirement age). Education affects wages and employment rates. The wage regression equation is given by the following

$$w_t = \exp(\varphi_0^w + \varphi_1^w(S_t) + \varphi_2^w \cdot Exper_t + \varphi_3^w \cdot Exper_t^2 \ + \ \varepsilon_t^w) \tag{3}$$

where $\varphi_1^w(S_t)$ is a function which summarizes the local returns to schooling and where

$$\varepsilon_t^w \sim \ N(0, \sigma_w^2(S_t))$$

is a stochastic shock which represents wage dispersion.

The employment rate equation is

$$e_t = \exp(\kappa_0 + \kappa_1 \cdot S_t + \kappa_2 \cdot Exper_t \ + \kappa_2 \cdot Exper_t^2 + \varepsilon_t^e)$$

with

$$\varepsilon_t^e \sim i.i.d. \ N(0, \sigma_e^2(S_t))$$

The stochastic shock ε_t^e represents employment rate dispersion. The dependence of both $\sigma_e^2(S_t)$ and $\sigma_w^2(S_t)$ on schooling attainment is crucial. It will allow us to measure how schooling decisions may be linked to wage and employment dispersion.

It is convenient to summarize the return to schooling in the following equation

$$\log Z_t = \varphi_0 + \varphi_1(S_t) + \varphi_2 \cdot Exper_t + \varphi_3 \cdot Exper_t^2 \ + \ \varepsilon_t$$

where

$$\varepsilon_t = \varepsilon_t^w + \varepsilon_t^e \sim i.i.d. \ N(0, \sigma^2(S_t))$$

$$\varphi_0 = \varphi_0^w + \kappa_0$$

$$\varphi_1(S_t) = \varphi_1^w(S_t) \ + \kappa_1$$

$$\varphi_2 = \varphi_2^w + \kappa_2$$

$$\varphi_3 = \varphi_3^w$$

2.2 The Solution

It is well known that the solution to the stochastic dynamic problem can be characterized using recursive methods. First, we must solve for the expected instantaneous (per period) utility and, secondly, we need to isolate the stochastic shock (ε_t^w) in order to obtain a closed-form solution for the probability of choosing to continue school or to enter the labor market.

The value functions associated to the decision to remain in school, $V_t^s(S_t)$, given that an individual has already acquired S_t years of schooling, can be expressed as

$$V_t^s(S_t) = \frac{\xi_t^{1-\alpha} - 1}{1-\alpha} + \beta\{\zeta(S_t) \cdot EV_{t+1}^I(S_{t+1}) + (1-\zeta(S_t)) \cdot EMax[V_{t+1}^s(S_{t+1}), V_{t+1}^w(S_{t+1})]\}$$

Given the absence of distinction between income during school interruption and income while in school, the value of entering a school interruption period, $V_t^I(S_t)$, is expressed in a similar fashion as $V_t^s(S_t)$, that is

$$V_t^s(S_t) = \frac{\xi_t^{1-\alpha} - 1}{1-\alpha} + \beta E(V_{t+1} \mid d_t = 1) \tag{4}$$

where $E(V_{t+1} \mid d_t = 1)$ denotes the value of following the optimal policy next period (either remain at school or start working) and where the expected value is taken over the distribution of potential labor market wages and employment rates.

The value of stopping schooling accumulation is the value of entering the labor market with S_t years of schooling and no labor market experience, $V_t^w(S_t)$, is given by

$$V_t^w(S_t) = \frac{(\exp(\varphi_0 + \varphi_1(S_t) + \ \varepsilon_t))^{1-\alpha} - 1}{1-\alpha} + \beta E(V_{t+1} \mid d_t = 0) \tag{5}$$

where $E(V_{t+1} \mid d_t = 0)$ denotes the discounted expected value of lifetime earnings of starting work in the labor market with t years of schooling, no labor market experience and T-t years of potential specific human capital accumulation ahead. Clearly,

$E(V_{t+1} \mid d_t = 0) =$

$$E \sum_{j=t+1}^{T} \beta^{j-(t+1)} \left\{ \frac{(\exp(\varphi_0 + \varphi_1(S_j) + \varphi_2 \cdot Exper_j + \varphi_3 \cdot Exper_j^2 \ + \ \varepsilon_j))^{1-\alpha} - 1}{1-\alpha} \right\} \tag{6}$$

Closed-form solution to the problem can be obtain by noting that

$$E(V_T) = EU(\exp(\ln(Z_T))) = E\frac{(\exp(\ln(Z_T)))^{1-\alpha} - 1}{1-\alpha} \tag{7}$$

and that

$$\int_{-\infty}^{+\infty} \frac{(\exp(\ln(Z_T)))^{1-\alpha} - 1}{1-\alpha} \; f_T(Z) \; dZ =$$

$$\frac{\exp\{\mu_T.(1-\alpha) + \frac{1}{2}\sigma_T^2 \cdot (1-\alpha)^2\} - 1}{1-\alpha} \tag{8}$$

where $f_T(Z)$ is the normal density with parameters μ_T and σ_T^2 and where

$$\mu_T = \varphi_0 + \varphi_1(S_T) + \; \varphi_2.Exper_T + \varphi_3.Exper_T^2 \tag{9}$$

The expected utility of entering any period can be solved using recursive methods (see Stokey and Lucas, 1989).

3 Empirical Specification

In the sample data, everyone has at least 6 years of education. As a consequence, we only model the decision to acquire schooling beyond six years. We also assume that the returns to accumulated education and experience at 65 (upon retirement) is 0 and that parental transfers are set to 0 upon entrance in the labor market.

3.1 The Utility of Attending School

Parental transfers are given by the following equation,

$$\log \xi_{it} = X_i'\delta + \upsilon_i^{\xi} \tag{10}$$

The vector X_i contains the following variables; parents' education (both mother and father), household income, number of siblings, family composition at age 14 and regional controls. The household composition variable (Nuclear Family) is equal to 1 for those who have been raised with both their biological parents (at age 14) and is likely to be correlated with the psychic costs of attending school. The geographical variables are introduced in order to control for the possibility that direct (as well as psychic) costs of schooling may differ between those raised in urban areas and those raised in rural areas and between those raised in the South and those raised in the North. The term υ_i^{ξ} represents unobserved taste for schooling and is described in Section (3.4).

3.2 Wages and Employment Rates

Observed wages, $\log \tilde{w}_{it}$, are assumed to be the sum of the true wage ($\log w_{it}$) and a measurement error (ε_{it}^m), that is the log wage (observed) regression is

$$\log \tilde{w}_{it} = \varphi_0 + \varphi_1(S_{it}) + \varphi_2.Exper_{i,t} + \varphi_3.Exper_{i,t}^2 + \upsilon_i^w + \varepsilon_{it}^w + \varepsilon_{it}^m$$

where υ_i^w is unobserved labor market ability affecting wages and where $\varepsilon_{it}^m \sim i.i.d.$ $N(0, \sigma_m^2)$. The employment equation is

$$\log e_{it} = \kappa_0 + \kappa_1 \cdot S_{i,t} + \kappa_2 \cdot Exper_{i,t} \ + \kappa_3 \cdot Exper_{i,t}^2 + \upsilon_i^\kappa + \varepsilon_{it}^e$$

The term υ_i^κ captures the effect of unobserved ability on employment rates and where $\varepsilon_{it}^e \sim i.i.d.\ N(0, \sigma_e^2)$

3.3 Earnings Dispersion and Education

We assume that the variance of wages and employment rates are heteroskedastic. The variances, $\sigma_e^2(S_t)$ and $\sigma_w^2(S_t)$ are given by the following,

$$\sigma_w(S_t) = \exp(\sigma_{w0} + \sigma_{w1} \cdot S_t + \sigma_{w2} \cdot S_t^2)$$

$$\sigma_e(S_t) = \exp(\sigma_{e0} + \sigma_{e1} \cdot S_t + \sigma_{e2} \cdot S_t^2)$$

3.4 Unobserved Ability in School and in the Labor Market

The intercept terms of the utility of attending school (υ_i^ξ), the employment rate equation (κ_{0i}) and of the log wage regression function (υ_i^w) are individual specific. We assume that there are K types of individuals. Each type is endowed with a vector of intercept terms $(\upsilon_k^w, \upsilon_k^\xi, \upsilon_k^\kappa)$ for $k = 1, 2...K$ and $K = 6$.

The distribution of unobserved ability is orthogonal to parents' background by construction. As a consequence, the distribution of ability which we estimate should be understood as a measure of unobserved ability remaining after conditioning on parents human capital. The probability of belonging to type k, p_k, are estimated using logistic transforms

$$p_k = \frac{\exp(q_k^0)}{\sum_{j=1}^6 \exp(q_j^0)}$$

and with the restriction normalize q_6 to 0.

3.5 Identification

With data on wages, employment rates and schooling attainments, it is straightforward to identify the key parameters the utility of attending school, the wage return to schooling, the employment return to schooling and unobserved school and market ability. This does not require further discussion (see Belzil and Hansen, 2001). The identification of the degree of risk aversion (α) is also straightforward to establish given knowledge of the variance of earnings (see equation 8).

However, the identification (and estimation) of a structural dynamic programming model always requires some parametric assumptions.[7] For instance, identification of the subjective discount rate relies on the standard assumption that preferences are time additive. Also, given that the model allows for unobserved taste for schooling, it is unrealistic to account for other sources of preference heterogeneity such as individual differences in risk aversion or in discount rates. This means that, given parents' background variables and unobserved market ability, observed differences in schooling are automatically imputed to differences in taste for schooling.[8]

3.6 Constructing the Likelihood

Dropping the individual subscript, the probability of investing in schooling in a given year is given by

$$\Pr(d_t = 1) = \Pr\left[V_t^s(S_t) \geq V_t^w(S_t)\right] = \Pr\{\frac{\xi_t^{1-\alpha} - 1}{1-\alpha} + \beta E(V_{t+1} \mid d_t = 1) \geq$$

$$\frac{(\exp(\ln(Z_t)))^{1-\alpha} - 1}{1-\alpha} + \beta E(V_{t+1} \mid d_t = 0)\} \tag{11}$$

or, equivalently, as

$$\Pr(d_t = 1) = \Pr\{(1-\alpha)Z_t \leq \log\left[\xi_t^{1-\alpha} + (1-\alpha)\beta[E(V_{t+1} \mid d_t = 1) - E(V_{t+1} \mid d_t = 0)]\right]\}$$

and can be expressed as follows.

$$\Pr(d_{it} = 1) = \Pr(\varepsilon_t \leq [\ h(S_t)]) = \Phi(\frac{h(S_t)}{\sigma_w(t)}) \tag{12}$$

[7] The degree of under-identification arising in the dynamic programming literature is discussed in Rust (1994) and Magnac and Thesmar (2001).

[8] While another possible estimation strategy could have been to include AFQT scores in the intercept terms of both the utility of attending school and the log wage regression function, we are reluctant to do so. This approach could lead to an understatement of the effects of schooling on wages and an understatement of risk aversion heterogeneity, if AFQT scores are themselves explained by schooling (see Rosenzweig and Wolpin, 2000)

where $h(S_t)$ is given by

$$h(S_t) = \frac{1}{1-\alpha} \cdot \log \left[(1-\alpha) \cdot (V_t^s(S_t) - \beta E(V_{t+1} \mid d_t = 0) + \frac{1}{1-\alpha}) \right] \} - \varphi_0 - \varphi_1(S_t)$$

The likelihood function is constructed from data on schooling attainments as well as the allocation of time between years spent in school ($I_t = 0, d_t = 1$) and years during which school was interrupted ($I_{t+1} = 1, d_t = 1$) and on employment histories (wage/unemployment) observed when schooling acquisition is terminated (until 1990). The construction of the likelihood function requires to evaluate the following probabilities;

- the probability of having spent at most τ years in school (including years of interruption), $Pr[(d_{i,0} = 1, I_0), (d_{i,1} = 1, I_1)....(d_{i,\tau} = 1, I_\tau)] = L_1$ and is easily evaluated using (11) and the definition of the interruption probability.
- the probability of entering the labor market, in year $\tau + 1$, at observed wage $\tilde{w}_{i,\tau+1}$, $P(d_{i,\tau+1} = 0, \tilde{w}_{i,\tau+1}) = L_2$, which can easily be factored as the product of a conditional times a marginal
- the density of observed wages and employment rates from $\tau + 2$ until 1990, $Pr\left(\{\tilde{w}_{i,\tau+2}, e_{i,\tau+2}\}..\{\tilde{w}_{i,1990}, e_{i,1990}\}\right) = L_3$, which is easily evaluated using the fact that the random shocks affecting the employment process and the wage process are mutually independent.

The log likelihood function, for a given individual, is given by

$$\log L_i = \log \sum_{k=1}^{K=6} p_k \cdot L_{1i(k)} \cdot L_{2i(k)} \cdot L_{3i(k)} \tag{13}$$

where each p_k represents the population proportion of type k.

4 The Data

The sample used in the analysis is extracted from the 1979 youth cohort of the *The National Longitudinal Survey of Youth (*NLSY). The NLSY is a nationally representative sample of 12,686 Americans who were 14-21 years old as of January 1, 1979. After the initial survey, re-interviews have been conducted in each subsequent year until 1996. In this paper, we restrict our sample to white males who were age 20 or less as of January 1, 1979. We record information on education, wages and on employment rates for each individual from the time the individual is age 16 up to December 31, 1990.

The original sample contained 3,790 white males. However, we lacked information on family background variables (such as family income as of 1978 and parents' education). We lost about 17% of the sample due to missing information regarding family income and about 6% due to missing information regarding parents' education. The age limit and missing information regarding actual work experience further reduced the sample to 1,710.

Descriptive statistics for the sample used in the estimation can be found in Table 1. The education length variable is the reported highest grade completed as of May 1 of the survey year and individuals are also asked if they are currently enrolled in school or not.[9] This question allows us to identify those individuals who are still acquiring schooling and therefore to take into account that education length is right-censored for some individuals. It also helps us to identify those individuals who have interrupted schooling. Overall, the majority of young individuals acquire education without interruption. The low incidence of interruptions (Table 1) explains the low average number of interruptions per individual (0.22) and the very low average interruption duration (0.43 year) . In our sample, only 306 individuals have experienced at least one interruption. This represents only 18% of our sample and it is along the lines of results reported in Keane and Wolpin (1997).[10] Given the age of the individuals in our sample, we assume that those who have already started to work full-time by 1990 (94% of our sample), will never return to school beyond 1990. Finally, one notes that the number of interruptions is relatively small.

The average schooling completed (by 1990) is 12.8 years. From Table 1, it is clear that the distribution of schooling attainments is bimodal. There is a large fraction of young individuals who terminate school after 12 years (high school graduation). The next largest frequency is at 16 years and corresponds to college graduation. Altogether, more than half of the sample has obtained either 12 or 16 years of schooling. As a consequence, one might expect that either the wage

[9]This feature of the NLSY implies that there is a relatively low level of measurement error in the education variable.

[10]Overall, interruptions tend to be quite short. Almost half of the individuals (45 %) who experienced an interruption, returned to school within one year while 73% returned within 3 years.

return to schooling or the parental transfers vary substantially with grade level. This question will be addressed below.

5 Structural Estimates and Goodness of Fit

In this section, we present a brief overview of some of the main structural parameter estimates which do not raise immediate interest and evaluate the goodness of fit of the model. The parameter estimates (found in Table A2) indicate that, other things equal, the utility of attending school increases with parents' education and income. This is well documented in various reduced-form studies as well as in many structural studies (see Belzil and Hansen, 2001, Eckstein and Wolpin, 1999 and Cameron and Heckman, 1998). The parameter estimates characterizing the distribution of all individual specific intercept terms (school ability, employment and wage regression and type probabilities) are also found in Table A2. The differences in intercept terms across types are indicative of the importance of unobserved ability affecting wages, employment rates and the utility of attending school.[11] The resulting type probabilities are 0.36 (type 1), 0.19 (type 2), 0.31 (type 3), 0.06 (type 4), 0.03 (type 5) and 0.06 (type 6). The spline estimates of the local returns to schooling, also found in Table A2, can be transformed into local returns (after adding up the proper parameters). More details on the return to schooling can be found in Belzil and Hansen (2001).

The predicted schooling attainments, along with actual frequencies are found in Table 1, and allow us to evaluate the goodness of fit. There is clear evidence that our model is capable of fitting the data well. In particular, our model is capable of predicting the very large frequencies at the most frequent grade levels (grade 12, grade16 and grade10).

[11] Similar results are reported in Belzil and Hansen (2001), Eckstein and Wolpin (2000) and Keane and Wolpin (1997).

Table 1
Model Fit: Actual vs Predicted Schooling Attainments

Grade Level	Predicted (%)	Actual (%)
6	0.0%	0.3 %
7	1.7%	0.6%
8	2.2%	2.9%
9	5.2%	4.7%
10	7.0%	6.0 %
11	8.9%	7.5 %
12	45.3%	39.6 %
13	5.8%	7.0 %
14	5.1%	7.7 %
15	1.5%	2.9 %
16	9.1%	12.9 %
17	5.1%	2.5 %
18	2.1%	2.4%
19	1.0%	1.3%
20-more	0.2%	1.6%

6 Risk Aversion, Earnings and Education: Some Results

In this section, we discuss the three following issues; the degree or risk aversion revealed in the data, the effect of education on earnings dispersion (as measured by the variances of wages and employment rates) and the effect of a counterfactual change in risk aversion on schooling attainment.

6.1 The Degree of Risk Aversion

Given the objectives of the paper, the estimates of the preference parameters are those that raise most interest. Our estimate of the discount rate, 0.0891, appears quite reasonable. In practice, the willingness to trade current wages for future wages is likely to be affected by imperfections in the capital market. The estimate of the degree of relative risk aversion, 0.9282 is however quite low when compared to estimates cited in the finance literature.[12] In order to illustrate the low degree of risk aversion, we examined the behavior toward risk of two types of labor market entrant (a high school graduate and a college graduate). Without

[12]See kocherlakota, 1996

loss of generality, we restrict ourself to a single period hourly wage lottery which is characterized by the parameters of the log wage distribution. We computed the certainty equivalent hourly wage rate and compared it with the expected hourly wage rate resulting from the within period lottery. The certainty equivalent is the certain wage rate, w_c, at which $w_c = U^{-1}(E(w))$. We have also computed the level of absolute risk aversion ($\frac{-U''(E(w))}{U'(E(w))}$) at the expected entry wage. Both measures of risk aversion (absolute and relative) as well as the expected wage and the certainty equivalent are found in Table 2. They illustrate the very low degree of risk aversion. A high school graduate, who who obtain on average an hourly wage rate of \$6.32, would be as well off with a certain wage of \$6.13. For a college graduate, the corresponding expected wage and certainty equivalent are equal to \$8.65 and 8.46.

Table 2
Measures of Risk Aversion

	High School Graduates	**College Graduates**
Relative Risk aversion (α)	0.9282	0.9282
Absolute Risk aversion $\frac{-U''(E(w))}{U'(E(w))}$	0.1469	0.1073
Expected wage (E(W))	6.3183	8.6478
Certainty equivalent ($w_c = U^{-1}(E(w))$)	6.1337	8.4579

Note: The degree of relative risk aversion, α, also equal to $\mathbf{-w \cdot \frac{U''(E(w))}{U'(E(w))}}$. The absolute degree of risk aversion is defined as $\mathbf{- \cdot \frac{U''(E(w))}{U'(E(w))}}$. The certainty equivalent wage, w_c, is defined as the solution of the following equation: $w_c = U^{-1}(E(w))$

6.2 The Effects of Education on Earnings Dispersion

In the empirical literature, homoskedasticity of the log wage regression function is rarely questioned. With a structural dynamic programming model taking into account individual unobserved heterogeneity, it is possible to distinguish the distribution of unobserved ability from the distribution of stochastic wage shocks.

The variance of stochastic wage shocks is a measure of wage dispersion and the effect of schooling on wage and employment rate variances can easily be computed. The quadratic specification of the log wage variance, along with estimates of σ_{w0} (-1.3739), σ_{w1} (0.0214) and σ_{w2} (-0.0032), which are found in Table A2, imply that wage dispersion will attain a maximum at 9 years of schooling and decrease thereafter. In practice, this means that wage dispersion decreases significantly with human capital for almost all individuals. At the same time, the estimates for σ_{e0} (-0.4084), σ_{e1} (0.0214) and σ_{e2} (-0.0032) imply that employment rate dispersion decreases monotonically with schooling attainments.

In order to establish more clearly the links between risk and education, we have computed the variances in lifetime wages, lifetime employment rates and lifetime earnings for all possible levels of schooling. All variances are measured over a period of 45 years of potential experience. The results are in Table 3. The decrease in employment rate and wage dispersion with schooling is well illustrated in columns 1 and 2. As earnings are defined as the product of an hourly wage rate times an employment rate, the variance in lifetime earnings also decreases dramatically with schooling attainments. The evidence suggests that schooling acquisition implies a significant reduction in total risk.

Table 3
Schooling Attainments and the variances of lifetime wages, employment rates and earnings

	Variance of Emp. rates (log)	**Variance of Wages (log)**	**Variance of Earnings (log)**
grade level			
7	16.02	2.99	19.01
8	12.64	3.06	15.70
9	9.78	3.09	12.87
10	7.41	3.09	10.50
11	5.50	3.04	8.54
12	4.00	2.96	6.96
13	2.85	2.84	5.70
14	1.99	2.70	4.69
15	1.36	2.52	3.89
16	0.91	2.33	3.25
17-more	0.60	2.13	2.73

Note: Variances are computed over a period of 45 years of potential experience

6.3 The Effect of Risk Aversion on Education

After having established the link between education and earnings dispersion, it is natural to investigate the relationship between risk aversion and education. As explained earlier, it is unrealistic to account for other sources of preference heterogeneity such as individual differences in risk aversion or in discount rates. While our model has been estimated under the assumption that preferences are homogenous (individuals differ in ability), it is easy to evaluate how mean schooling attainments change with a counterfactual change in risk aversion. This counterfactual experiment may be viewed as an evaluation of the importance of the differences in schooling attainments between various sub-groups of the population endowed with different levels of risk aversion. For the sake of comparison with the results usually reported in the empirical finance literature, we have computed mean schooling attainments for levels of relative risk aversion between 0.93 and 3.00. These are found in Table 3. These simulations indicate that, over the range considered, mean schooling attainments will increase with risk aversion. For instance, at a relatively high degree of risk aversion such as $\alpha = 3.0$, individuals would obtain, on average, 18.50 years of schooling.

Table 4
Risk Aversion and Expected Schooling Attainments

Relative Risk Aversion (α)	**Mean Schooling**
$\alpha = 0.93$	12.45 years
$\alpha = 1.00$	12.49 years
$\alpha = 1.5$	13.65 years
$\alpha = 2.0$	16.19 years
$\alpha = 3.0$	18.50 years

7 Some Elasticities of Schooling Attainments

In this section, we evaluate the elasticities of mean schooling attainments with respect to changes in some of the key parameters of the model. In particular, we investigate individual reactions to changes in the wage and employment returns to schooling as well as changes in schooling attainments due to changes in school and wage subsidies.

7.1 How do people react to changes in the returns to education

Using counterfactual changes in the return to schooling, it is easy to evaluate mean schooling attainments elasticities. As the wage return to schooling is estimated flexibly, we simulated changes in the overall return and also simulated changes in the return to college graduation. The elasticities with respect to the wage return, reported in Table 5, are 0.35 (for an overall increase) and 0.11 (for an increase in the return to college graduation). Schooling attainments are therefore relatively inelastic with respect to the wage return to schooling.

7.2 How do people react to changes in school Subsidies and Wage Subsidies

As for the wage return to schooling, it is possible to evaluate the elasticities of schooling attainments with respect to an overall increase in earnings while at school (school subsidies) or a subsidy to post high-school education. As expected, the elasticity with respect to a general increase (1.01) exceeds the elasticity to post high-school education (0.46). When compared to the elasticities reported in 7.1, these elasticities indicate that individual are more responsive to school subsidies (or parental transfers) than to the return to schooling. Finally, by increasing the intercept term of the wage regression, it is possible to simulate the effect of a wage subsidy. It is well known that an overall increase in wages will result in an increase in the opportunity costs of schooling. Not surprisingly, our results indicate that the elasticity of schooling attainments with respect to a wage increase is negative (-0.70) and strong.

As a conclusion, schooling attainments appear more sensitive to changes in the utility of attending school than to changes in the return to schooling. This is consistent with findings reported in Belzil and Hansen (2000,a), Keane and Wolpin (1997) and Eckstein and Wolpin (1999) and can be explained by the importance of individual differences in school ability.

7.3 How do people react to changes in risk

Our flexible specification of the log wage and the log employment regression functions allow us to investigate how individuals react to changes in risk. In particular, the heteroskedastic function for the variances allow us to evaluate the effects of an overall change in earnings dispersion. Log normality implies that $E(Z) = \exp(\mu + 0.5 \cdot \sigma^2)$ and $Var(Z) = \exp(2\mu + \sigma^2) \cdot (\exp(\sigma^2) - 1)$. In order to do so, we must change the variance of the log earnings regression (σ_1) and adjust the mean of the log earnings (μ) so that only earnings dispersion is changed. The elasticity with respect to a change in risk is found to be small and positive (0.07). The positive sign can be explained as follows. An increase in earnings risk

makes parental transfers relatively more appealing for risk averse individuals. As a consequence, young individuals respond by staying in school longer. However, given the very low level of risk aversion, the effect is small.

Table 5
Various Elasticities of Expected Schooling Attainments

Parameters	**elasticities**
Wage Return	
all levels	0.35
grade 16	0.11
School Subsidies	
all levels	1.01
post high school	0.46
Wage subsidies	-0.70
Risk	
Earnings (σ^2)	0.0700

8 Conclusion

We have estimated a dynamic programming model of schooling decisions in which risk averse individuals make optimal sequential schooling decisions based on the fact that accumulated schooling affects the both the mean and the variance of lifetime wages and employment rates. Our model fits the data quite well and the results indicate that individuals have a very low degree of risk (relative) aversion. The parameter estimate of the degree of risk aversion, 0.9282, is just somewhat below the degree of risk aversion found in logarithmic preferences. At the same time, our estimates of log wage and log employment rate regression functions indicate that, after conditioning on individual specific unobserved ability, wage dispersion and employment rate dispersion are highly heteroskedastic. More precisely, both wage and employment rate dispersions decrease with schooling. This is consistent with the hypothesis that risk sharing agreement are more common among highly educated (high wage) workers. Not surprisingly, mean schooling attainments are found to be increasing in risk aversion.

We have used our model to simulate the effects of a change in the returns to education, a change in school (and wage) subsidies and a change in risk on expected schooling attainments. The results indicate that schooling attainments

are relatively more elastic with respect to school subsidies than to the return to schooling. Consistent with the low degree of risk aversion disclosed in the data, an increase in earnings dispersion (an increase in the overall variance of wages and employment rates) will raise schooling by a relatively small number and the elasticity is quite small (around 0.07). Finally, we find that a counterfactual increase in the degree of risk aversion will increase schooling attainments. .

These findings suggest avenues for future research. As education can play the role of self-insurance, it would be interesting to analyze the optimality of social insurance in a context where human capital (schooling) is a substitute for social insurance. Finally, it would be interesting to analyze optimal schooling decisions in a context where workers can explicitly enter contractual agreements with potential employers.

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Table A1- Descriptive Statistics.

Variable	Mean	Std. Dev.	# Individuals
prop. raised in urban areas	0.70	-	1019
father's educ (years)	11.27	3.43	1019
mother's educ (years)	11.34	2.54	1019
family income in 1978	37,685	27,224	1019
number of siblings	3.25	2.15	1019
prop. growing up in nuclear family	0.79	-	1019
prop. raised in southern states	0.28	-	1019
AFQT score	42.43	28.02	1019
education completed (as of May 1990)	12.25	2.45	1019
prop. students (in 1990)	0.01	-	1019
wage 1979 (per hour)	6.61	2.09	86
wage 1980(per hour)	6.55	2.41	224
wage 1981 (per hour)	6.74	2.64	342
wage 1982 (per hour)	6.93	2.92	496
wage 1983 (per hour)	6.74	2.79	593
wage 1984 (per hour)	7.09	3.23	683
wage 1985 (per hour)	7.65	3.25	719
wage 1986 (per hour)	8.30	3.57	732
wage 1987 (per hour)	9.08	4.16	775
wage 1988 (per hour)	9.79	4.60	830
wage 1989 (per hour)	9.93	4.72	826
wage 1990 (per hour)	10.45	4.86	823

Notes:
Family income and hourly wages are reported in 1990 dollars. Family income is measured as of May 1979 (for 1978). The increasing number of wage observations (until 1988) is explained by the increase in participation rates (schooling completion).

Table A2
Structural Parameter Estimates

	Parameter	Std error
Utility in School		
Father's Educ	0.0158	0.0010
Mother's Educ	0.0115	0.0011
Family Income/1000	0.0009	0.0002
Nuclear Family	0.0382	0.0050
Siblings	-0.0108	0.0010
Rural	-0.0071	0.0091
South	-0.0209	0.0099
Risk Aversion	0.9282	0.0390
Discount Rate	0.0891	0.0031
Employment		
Schooling	0.0116	0.0010
Exper.	0.0027	0.0005
Exper^2.	-0.0001	0.0000
σ_0^e (intercept)	-0.4084	0.0372
σ_1^e (schooling)	-0.1030	0.0120
σ_2^e (schooling^2)	-0.0051	0.0009
Wages		
spline 7-10	0.0070	0.0045
spline 11	0.0030	0.0004
spline 12	0.0407	0.0048
spline 13	-0.0820	0.0040
spline 14	0.0680	0.0046
spline 15	-0.0305	0.0053
spline 16	0.0489	0.0067
spline 17-more	-0.0325	0.0038
Exper	0.1034	0.0044
Exper^2	-0.0044	0.0004
σ_0^w (intercept)	-1.3739	0.0302
σ_1^w (schooling)	0.0214	0.0102
σ_2^w (schooling^2)	-0.0032	0.0010
Measurement error		
σ_m^2	0.1444	0.0016
interruption prob		
ζ_7	0.0124	0.0103
ζ_8	0.0621	0.0234

Table A2- Continued
Structural Parameter Estimates

	Parameter	**St Error**
ζ_9	0.0937	0.0248
ζ_{10}	0.0270	0.0249
ζ_{11}	0.1167	0.0072
ζ_{12}	0.3420	0.0190
ζ_{13}	0.1004	0.0476
ζ_{14}	0.1217	0.0216
$\zeta_{15-more}$	0.1220	0.0119
Unobs. Hetero.		
Type 1		
School ab. (υ_1^{ξ})	-1.2147	0.0473
Wage (υ_1^{w})	1.3463	0.0094
Employment υ_1^{κ}	-3.3629	0.0301
Type Prob. (q_1^0)	1.6875	0.0419
Type 2		
School ab. (υ_2^{ξ})	-0.8354	0.0481
Wage ab. (υ_1^{w})	1.6785	0.0192
Employment υ_1^{κ}	-0.1615	0.0113
Type Prob (q_2^0)	1.0255	0.0378
Type 3		
School ab. (υ_3^{ξ})	-1.4983	0.0453
Wage (υ_1^{w})	1.0529	0.0121
Employment (υ_1^{κ})	-0.1560	0.0241
Type Prob (q_3^0)	1.5402	0.0098
Type 4		
School ab. (υ_4^{ξ})	-1.8252	0.0532
Wage (υ_4^{w})	1.1546	0.0112
Employment (υ_1^{κ})	-0.5491	0.0204
Type Prob (q_4^0)	0.1578	0.1396
Type 5		
School ab. (υ_5^{ξ})	-2.3599	0.0538
Wage (υ_1^{w})	1.2591	0.0121
Employment (υ_1^{κ})	-1.0950	0.0269
Type Prob (q_5^0)	-1.1992	0.1913
Type 6		
School ab. (υ_6^{ξ})	-1.8127	0.0456
Wage (υ_1^{w})	0.7072	0.0106
Employment (υ_1^{κ})	-0.2005	0.0141
Type Prob (q_6^0)	0.0 (normalized)	
mean Log Likelihood	-8.02289	