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Wage Risk and Employment Risk over the Life Cycle

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We specify a life-cycle model of consumption, labor supply and job mobility in an economy with search frictions. We distinguish different sources of risk, including shocks to productivity, job arrival, and job destruction. Allowing for job mobility has a large effect on the estimate of productivity risk. Increases in the latter impose a considerable welfare loss. Increases in employment risk have large effects on output and, primarily through this channel, affect welfare. The welfare value of programs such as Food Stamps, partially insuring productivity risk, is greater than the value of unemployment insurance which provides (partial) insurance against employment risk. (*JEL* D91, J22, J31, J61, J64, J65)

There is an extensive literature analyzing individuals' precautionary responses to income risk under incomplete markets. The theoretical literature has clarified the circumstances under which precautionary behavior arises. Empirical analysis has concentrated on assessing the levels of income risk and the persistence of shocks;[1] on showing that insurance markets are indeed incomplete;[2] and on measuring the effects of uninsurable idiosyncratic risk on life-cycle consumption profiles and wealth accumulation.[3] In most studies idiosyncratic risk is identified as the variance of an appropriately defined residual in a panel data model of income, but the underlying sources of risk are not distinguished, and exogenous shocks are not disentangled from the effects of actions (such as changes in labor supply and job mobility) taken in response to such shocks. While we have learned a lot from this first generation of models, to obtain a better understanding of individual responses to risk and to carry out policy analysis, it is necessary to go deeper and to understand the sources of risk and to recognize that many of the observed fluctuations are the result of endogenous choices. Indeed the key first steps for assessing the effects on allocations and welfare of various social insurance policies that are designed to help deal with risk are to understand and to quantify the underlying sources of the uncertainty that individuals face.

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[1] For example, see Thomas E. MaCurdy (1982), John M. Abowd and David Card (1989), Meghir and Luigi Pistaferri (2004), and Fatih Guvenen (2007).

[2] See John H. Cochrane (1991) and Orazio Attanasio and Stephen J. Davis (1996).

[3] See amongst others Stephen P. Zeldes (1989); Angus Deaton (1991); Christopher D. Carroll (1992); Carroll and Andrew A. Samwick (1997); James Banks, Richard Blundell, and Agar Brugiavini (2001); Pierre-Olivier Gourinchas and Jonathan A. Parker (2002); and Attanasio, Banks, Meghir, and Guglielmo Weber (1999).

In order to disentangle shocks from the responses to the shocks, we specify a structural life-cycle model of consumption, labor supply, and job mobility. We then specify the underlying sources of shocks that are the key drivers of observed fluctuations in earnings. These include shocks to individual productivity that persist across different jobs and across time; firm-level shocks that lead to job destruction; the stochastic process of job offers when employed and unemployed; and variation in the quality of the match offered. Our model captures how these basic underlying shocks transmit into observed behavior, welfare, and earnings fluctuations. Without the labor supply and job mobility choices, we would obtain a misleading picture of the extent to which individuals can self-insure and the extent to which observed earnings fluctuations reflect risk.[4]

Within our framework, we can distinguish between employment risk and productivity risk. Productivity risk is individual-specific uncertainty that exists independently of the employer's characteristics. Employment risk captures the uncertainty about having a job and also about the firm type. This includes the possibility of firm closure or job destruction, the difficulty of finding a new job while unemployed, and the extent of unobserved heterogeneity across firms. In a fully competitive labor market with no worker-firm match heterogeneity and no search costs, the distinction between employment and productivity risk would be meaningless because unemployment would arise only due to low productivity resulting in the individual's market wage being below the reservation wage. Unemployment itself would not be a source of risk.[5]

Shocks differ in their available insurance opportunities. For example, layoffs are usually partially insured by the unemployment insurance system, while individual productivity shocks, other than major observable health shocks, are rarely insured in any formal way because of moral hazard and limited enforcement and commitment reasons. It is precisely this lack of formal insurance that prompts prudent individuals to engage in precautionary behavior. Furthermore, the individual's response to earnings risk will depend partly on the availability of outside insurance—private or public. With few exceptions (R. Glenn Hubbard, Jonathan S. Skinner, and Zeldes 1995), the literature on precautionary savings has assumed that only self-insurance is available. In this paper, we propose a model in which people can self-insure but may also be eligible for government-provided insurance mirroring three popular programs in the United States: Unemployment Insurance (UI), Disability Insurance (DI), and Food Stamps. These systems provide partial insurance only.

The parameters of our model are obtained partly from estimating the characteristics of the wage process with endogenous employment and mobility choices, and partly from calibrating our life-cycle model to fit observed employment profiles and unemployment durations. We use longitudinal wage and job mobility data from the Survey of Income and Program Participation (SIPP) and employment and unemployment duration data from the Panel Study of Income Dynamics (PSID).

The empirical results we report relate to the nature of the income process and the basic implications of the model. First, we show that our preferred stochastic process for income (the sum of a random walk, an i.i.d. component, and a firm-worker match fixed effect) provides a good fit of the key facts in the data. Second, we find that if mobility is ignored the estimated variance of the permanent innovation to wages doubles, leading to an impression of much greater risk in the earnings process. This is because many of the wage fluctuations are due to individuals moving to jobs with better match-specific effects; ignoring this biases measured uncertainty upwards.

[4] Per L. Krussell et al. (2008) highlight the importance of modeling labor market frictions alongside labor supply choices in understanding the aggregate implications of incomplete markets.

[5] Some recent papers have analyzed the joint precautionary saving-labor supply decision. Low (2005), Josep Pijoan-Mas (2006), and David Domeij and Martin Floden (2006) analyze the joint saving and labor supply decision, but in a context without exogenous job destruction, search frictions, or job mobility. Eric French (2005) analyzes labor supply and savings behavior but focuses on older workers. Jonathan Heathcote, Kjetil Storesletten, and Giovanni L. Violante (2007) consider a joint saving-labor supply decision, again without frictions, and focusing on the degree of partial insurance. Jeremy Lise (2010) uses a model with search frictions and consumption to link the empirical earnings and wealth distributions.

Turning to counterfactual experiments, we assess the effects of different types of risk by varying some key parameters one at a time (including the variance of productivity risk, and the job destruction rate) and reporting the change in labor supply, output, and savings. We also compute the willingness to pay to avoid the various changes in risks. Changes in these sources of risk affect the level of individual output, as well as the variance. This is because changes in risk change labor market participation. Some of these changes are exogenous: greater job destruction directly reduces employment; others are endogenous: greater variability in productivity leads to wage offers being more likely to fall below an individual's reservation wage. When productivity risk increases, therefore, individuals are worse off because of the increased risk but also because output declines. However, individuals are willing to pay substantially more than the output loss to compensate for the increased risk. When job destruction increases, output also declines and unemployment increases, as we would expect. The environment becomes riskier as highly valued jobs can be lost at a faster rate, but the welfare effects of this risk are mitigated by the utility value of leisure (which in our model is a substitute for consumption). Overall, although welfare falls as job destruction increases, the willingness to pay to return to the original lower rate of job destruction is *less* than the loss in output.

To compare the two risks we consider, first, changing the variance of productivity shocks and, second, changing the rate of job destruction so as to achieve a decline of 5 percent in the variance of income growth. We compute the willingness to pay for each of these two changes. Individuals value more the decline in productivity risk than the decline in the rate of job destruction, both of which achieve the same decline in the variance of income growth. The underlying reason is that, in contrast to permanent productivity shocks to wages, job destruction leads to a transitory shock in income.

Finally, we measure the value that people assign to an increase in the various government-provided insurance programs in our model and compare this to the value of a revenue equivalent cut in proportional taxes. The welfare value of programs such as Food Stamps, which partially insure productivity risk, is greater than the value of unemployment insurance, which provides (partial) insurance against employment risk and no insurance against persistent shocks. This relatively low value of unemployment insurance is in line with the results of Gary D. Hansen and Ayşe İmrohoroğlu (1992).[6]

The layout of the paper is as follows. Section I presents the model and discusses the distinction between employment and productivity risk. Section II describes the data. Section III describes the estimation strategy and results for estimating the wage process. Section IV presents the calibration process for the remaining parameters. Section V discusses possible alternatives to our wage process. Section VI presents our calculations of the behavioral effects and the welfare costs of uncertainty and the welfare benefit of government insurance programs, followed by conclusions.

I. Model

A. *Overview*

We specify a model where individuals choose consumption and make work decisions so as to maximize an intertemporal utility function, in an environment with search frictions. We view the

[6] Rasmus Lentz (2009) also analyzes the value of unemployment insurance, allowing for the interaction between search frictions and saving. James S. Costain (1997) proposes an equilibrium search model with precautionary savings that attempts to measure the welfare effects of unemployment insurance. Silvio Rendon (2006) examines the relationship between wealth accumulation and job search dynamics in a model where the motivation for accumulating wealth is to finance voluntary quits in order to search for a better job. However, all these papers, along with Hansen and İmrohoroğlu (1992), ignore the risk to individuals' own productivity which is independent of any particular match.

key sources of shocks underlying earnings fluctuations as being shocks to individual productivity, firm-level shocks leading to job destruction, the process of job offers when unemployed and when employed, and the quality of the match offered. Thus individuals face multiple sources of uncertainty: in each period employed individuals may be laid off or may receive offers of alternative employment; unemployed workers may or may not be offered a job; all individuals face uninsurable shocks to their productivity.

The economy offers partial social insurance in the form of a number of programs. These are Food Stamps, Unemployment Insurance, Disability Insurance, and Social Security (pensions). In the model simulation, changes to these programs are funded by proportional taxation; thus individuals are linked through the government budget constraint. The model has numerous sources of dynamics. These include asset accumulation, the fact that job offer probabilities are state dependent, and that current actions affect future eligibility for the various programs. We consider two types of individual separately: the lower-educated individuals, which include all those with a high school diploma or less, and the higher-educated individuals with at least some college.

In this section we start by describing the stochastic process of wages. Then we describe the process of job arrival and job destruction. With the sources of shocks specified we then describe the individual optimization problem and the distinction between employment and productivity risk. The empirical analysis follows in the next sections.

B. *Structure of Wages and Shocks*

We begin the model specification by outlining the process for wages. We assume that wages w_{it} in the data are governed by the process:

$$\ln w_{it} = d_t + x_{it}'\psi + u_{it} + e_{it} + a_{ij(t_0)} \tag{1}$$

where w_{it} is the real hourly wage, d_t represents the log price of human capital at time t, x_{it} a vector of regressors including age, u_{it} the permanent component of wages, and e_{it} the transitory error component. All parameters of the wage process are education specific.

In principle, the term e_{it} might be thought to represent a mix between a transitory shock and measurement error. In the usual decomposition of shocks into transitory and permanent components, researchers work with annual earnings data where transitory shocks may well be important because of unemployment spells. In our framework, this source of transitory shocks is modeled explicitly through employment and job mobility. We show below that the model generates a stochastic process for earnings similar to that estimated using earnings from, say, the PSID. Thus, we assume that all estimated transitory shocks to wages represent measurement error.[7]

The term $a_{ij(t_0)}$ denotes a firm-worker match-specific component where $j(t_0)$ indexes the firm that the worker joined in period $t_0 \leq t$.[8] It is drawn from a normal distribution with mean zero and variance σ_a^2. We model the match effect as constant over the life of the worker-employer relationship. If the worker switches to a different employer between t and $t+1$, however, there will be some resulting wage growth which we can term a mobility premium denoted as $\xi_{it+1} = a_{ij(t+1)} - a_{ij(t_0)}$. Successive draws of $a_{ij(t)}$ are assumed independent; however, because of the endogenous mobility decisions, successive *realizations* of the match effect will be correlated. Since offers can

[7] Further, in the empirical section we find that the variance of e_{it} is low, and indeed lower than the variance of measurement error obtained on annual earnings by validation studies on the SIPP data (see Abowd and Martha H. Stinson 2005).

[8] We should formally have a j subscript on wages, but since it does not add clarity we have dropped it. Note also that in the absence of firm data one cannot distinguish between a pure firm effect and a pure match effect. In the latter case, one can imagine $\alpha_{ij(t_0)}$ as being the part of the matching rent that accrues to the worker. We take the bargaining process that produces this sharing outcome as given.

be rejected when received, only a censored distribution of ξ_{it+1} is observed. The match effect $a_{ij(\cdot)}$ is complementary to individual productivity.[9] Both the match effect and the idiosyncratic shock have education-specific distributions. The information structure is such that workers and firms are completely informed about u_{it} and $a_{ij(\cdot)}$ when they meet (jobs are "search goods"). The importance of match effects in explaining wages has been stressed by Robert H. Topel and Michael P. Ward (1992) and Abowd, Francis Kramarz, and David N. Margolis (1999). Fabien Postel-Vinay and Jean-Marc Robin (2002) show in an equilibrium setting how firm and individual heterogeneity translate into a match effect.

Finally, we assume that there are constant returns to scale in labor, implying that the firm is willing to hire anyone who can produce nonnegative rents. However, we assume the firm does not respond to outside offers. If firms did respond, this would imply that the match-specific effect would increase each period with some probability and would manifest itself as a return to job tenure. However, returns to tenure are thought to be small, once one controls for endogeneity of job mobility.[10] This provides some evidence that outside offers are not an important source of wage growth on the job. While dealing with the effect of outside offers may be interesting, we leave this for future research.

We assume that the permanent component of wages follows a random walk process:

$$u_{it} = u_{it-1} + \zeta_{it}. \tag{2}$$

The random shock to the permanent process, ζ_{it}, is normally distributed with mean zero and variance σ_ζ^2 and is independent over time. We assume this shock reflects uncertainty.[11] We assume that the permanent shock, ζ_{it}, occurs each quarter with probability 0.25. Thus, on average, the permanent component of wages changes once per year.

Given a particular level of unobserved productivity, the worker will be willing to work for some firms but not for others, depending on the value of the match. We assume that the measurement error e_{it} is normally distributed with variance σ_e^2 and independent over time. As far as the policy implications of the model are concerned, we are interested in estimating σ_a^2 and σ_ζ^2. We describe later how these are estimated.

The specification we present, while consistent with much of the evidence and in line with a number of papers,[12] is not uncontroversial. Two alternatives might be a model with a stationary AR(1) process with a fixed effect in wage growth[13] or a model where the match-specific effect evolves stochastically over time. We discuss these alternatives in Section V and justify our choice.

[9] Ideally we would like to allow also for shocks to the match effect. These will act as within-firm aggregate shocks. Restricting match effects to be constant is forced upon us by the lack of matched firm and individual data. In Section V, we consider the alternative assumption of modeling individual productivity as a fixed effect and the match component as a random walk.

[10] Joseph G. Altonji and Nicolas Williams (2005) assess this literature and conclude that their preferred estimate for the United States is a return to tenure of 1.1 percent a year.

[11] An issue is how much of the period-to-period variability of wages reflects uncertainty. A large component of this variability is measurement error, which we control for. Beyond that, primarily for lack of adequate data, we abstract from the important issues that have to do with consumers having superior information vis-à-vis the econometrician. For discussions and empirical analysis see Blundell and Ian Preston (1998); Charles F. Manski (2004); Pistaferri (2001, 2003); and Flavio Cunha, James J. Heckman, and Salvador Navarro-Lozano (2005).

[12] See MaCurdy (1982), Topel (1991), Abowd and Card (1989), Robert A. Moffitt and Peter Gottschalk (1995), and Meghir and Pistaferri (2004).

[13] This is sometimes referred to as the "random growth model."

C. *Job Destruction and Job Arrival Rates*

In each period workers receive an alternative job offer with probability λ^e. Those who are currently unemployed receive an offer with probability λ^n. Individuals become unemployed either because they choose to quit following particular wage realizations or because of exogenous job destruction, which happens each period with probability δ. The friction parameters (as well as the variance parameters discussed earlier) are all assumed to be specific to an education group.

The composition of those becoming unemployed is not random in our model, despite the fact that the job destruction rate acts as a random shock independently of individual skill levels. First, people with bad productivity shocks will quit their jobs, and the extent to which this happens depends on the variance of the wage innovations. Second, the job destruction rates can differ by education group. Thus there is selection into the unemployment pool in terms of both observable and unobservable skill characteristics, and this selection means those becoming unemployed are less productive on average than the employed.

We assume there is no exogenous depreciation of skills following job loss. Instead, the loss of the particular match on entering unemployment may lead to wages on reentry being lower because the new firm will on average have a lower match value. This is the case because individuals in work will have improved over the average offer through job mobility, before a job in which they are employed is destroyed.[14] Thus firm heterogeneity implies that exogenous job destruction will lead to wage losses and appear as "scarring," which we document in the empirical analysis below.

We assume that job destruction and job offer arrival rates are constant over time, and so we ignore business-cycle effects. We focus instead on the implications of idiosyncratic risk for behavior and for welfare. By contrast, Robert E. Lucas (1987) and others focus on the welfare benefit of smoothing out the aggregate business-cycle risk, and Storesletten, Chris I. Telmer, and Amir Yaron (2001) focus on smoothing out the variation in idiosyncratic risk. In our comparative static analysis, however, we show the effects of different values of job destruction and job offer arrival rates across a range consistent with the variation observed over the business cycle.

D. *Individual Optimization*

We consider an individual with a period utility function

$$U_t = U(c_{it}, P_{it})$$

where P is a discrete $\{0, 1\}$ employment variable and c is consumption. The individual is assumed to maximize lifetime expected utility,

$$\max_{c,P} V_{it} = E_t \sum_{s=t}^{L} \beta^{s-t} U(c_{is}, P_{is})$$

where β is the discount factor and E_t the expectations operator conditional on information available in period t (a period being a quarter of a year). Individuals live for L periods, may work from age 22 to 62, and face an exogenous mandatory spell of retirement of 10 years at the end of life. The date of death is known with certainty.

[14] Indeed, as stated by Louis S. Jacobson, Robert J. LaLonde, and Daniel G. Sullivan (1993), "workers possessing skills that were especially suited to their old positions are likely to be less productive, at least initially, in their subsequent jobs. Such a fit between workers' skills and the requirements of their old jobs could have resulted from on-the-job investment in firm-specific human capital or from costly search resulting in particularly good match with their old firms."

The labor supply choice in our model is a discrete choice. However, since one period is one quarter, this discrete choice can generate substantial variation in annual hours of work.[15] The worker's problem is to decide whether to work or not if an offer is available and, if the opportunity arises, whether to switch firms. When unemployed he has to decide whether to accept a job that may have been offered or wait longer. If eligible, the unemployed person will have the option to apply for disability insurance. Whether employed or not, the individual has to decide how much to save and consume. Accumulated savings can be used to finance spells out of work and early retirement.

We use a utility function of the form

$$U(c,P) = \frac{(c \times \exp\{\eta P\})^{1-\gamma}}{1-\gamma}.$$

We consider cases where $\gamma > 1$ and $\eta < 0$, implying that individuals are reasonably risk averse, working reduces utility, and that consumption and employment are Frisch complements (i.e., the marginal utility of consumption is higher when working). We use this specification because it is consistent with findings showing that consumption and leisure are not additively separable.[16]

The intertemporal budget constraint during the working life has the form

$$(3) \quad A_{it+1} = R[A_{it} + (w_{it}h(1 - \tau_w) - F_{it})P_{it} + (B_{it}E_{it}^{UI}(1 - E_{it}^{DI}) + D_{it}E_{it}^{DI})(1 - P_{it}) + T_{it}E_{it}^{T} - c_{it}]$$

where A is beginning-of-period assets, R is the interest factor, w the hourly wage rate, h a fixed number of hours (corresponding to 500 hours per quarter), τ_w a proportional tax rate that is used to finance social insurance programs, F the fixed cost of work, B_{it} unemployment benefits, T_{it} the monetary value of food stamps received, D_{it} the amount of disability insurance payments obtained, and E_{it}^{UI}, E_{it}^{DI}, and E_{it}^{T} are recipiency $\{0,1\}$ indicators for unemployment insurance, disability insurance, and the means-tested transfer program, respectively. Note also that there are costs of applying for disability insurance which we discuss below.

We assume that individuals are unable to borrow either against the social insurance programs or against future earnings:

$$A_{it} \geq 0.$$

In practice, this constraint has bite because it precludes borrowing against unemployment insurance, disability insurance, Social Security, and the means-tested program.

At retirement, people collect Social Security benefits which are paid according to a formula similar to the one we observe in reality (see below). These benefits, along with assets that people have voluntarily accumulated over their working years, are used to finance consumption during retirement.

[15] In the data, the variation in annual hours is predominantly due to changes in employment status during the year. By using a quarter as the decision time we are able to generate substantial variation over the year. Hours elasticities for workers are found to be very small in most empirical microeconomic studies for men; see MaCurdy, David Green, and Harry J. Paarsch (1990); John Pencavel (2002); and Meghir and David Phillips (2010) as examples.

[16] See Heckman (1974) on the importance of such nonseparability and Blundell, Martin Browning, and Meghir (1994); and Attanasio and Weber (1995) on empirical results.

Unemployment Insurance.—We assume that unemployment benefits are paid only for the quarter immediately following job destruction. We define eligibility for unemployment insurance E_{it}^{UI} to mirror current legislation: benefits are paid only to people who have worked in the previous period, and only to those who had their job destroyed (job quitters are therefore ineligible for UI payments, and we assume this can be perfectly monitored).[17] We assume $B_{it} = b w_{it-1} \overline{h}$ subject to a cap, and we set the replacement ratio $b = 75$ percent. The replacement ratio is set at this high value because the payment that is made is intended to be of a magnitude similar to the maximum available to someone becoming unemployed. The cap is set according to the median state (Bruce D. Meyer 2002).

In the United States, unemployment benefit provides insurance against job loss and insurance against not finding a new job. However, under current legislation benefits are provided only up to 26 weeks (corresponding to two periods of our model), and so insurance against not finding a new job is limited. Our assumption is that there is no insurance against the possibility of not receiving a job offer after job loss. This simplifying assumption means that unemployment benefit is like a lump-sum payment to those who exogenously lose their job. This implies that UI introduces only two types of distortion on labor supply. The first is due to the tax on wages that finances the program. The other is the effect of UI payments on asset accumulation decision, which in turn affects job acceptance.

Universal Means-Tested Program.—In modeling the universal means-tested program, our intention was to mirror partially the actual Food Stamps program but with three simplifying differences. First, the means testing is only on income rather than on income and assets;[18] second, the program provides a cash benefit rather than a benefit in kind;[19] and third, we assume there is a 100 percent take-up. These assumptions mean that in our model there is no direct disincentive for poor individuals to hold assets (as in Hubbard, Skinner, and Zeldes 1995); there is still, however, the disincentive to accumulate caused by the programs, as the public insurance will lead to a lower need for precautionary savings.

For the purposes of the program gross income is defined as

$$y_{it}^{gross} = w_{it} h P_{it} + (B_{it} E_{it}^{UI} (1 - E_{it}^{DI}) + D_{it} E_{it}^{DI})(1 - P_{it}) \tag{4}$$

giving net income of $y = (1 - \tau_w) y^{gross} - d$, where d is the standard deduction that people are entitled to when computing net income for the purpose of determining food stamp allowances. The value of the program is then given by

$$T_{it} = \begin{cases} \overline{T} - 0.3 \times y_{it} & \text{if } y_{it} \leq \underline{y} \\ 0 & \text{otherwise} \end{cases} \tag{5}$$

[17] We have simplified considerably the actual eligibility rules observed in the United States. A majority of states have eligibility rules that are tougher than the rule we impose, both in terms of the number of quarters necessary to be eligible for any UI and in terms of the number of quarters of work necessary to be eligible for the maximum duration (Meyer 2002). However, making eligibility more stringent in our model is numerically difficult because the history of employment would become a state variable. Our assumption on eligibility shows UI in its most generous light.

[18] The difficulty with allowing for an asset test in our model is that there is only one sort of asset that individuals use for retirement saving as well as for short-term smoothing. In reality, the asset test applies only to liquid wealth and thus excludes pension wealth (as well as real estate wealth and other durables). Finally, note that in 1996 a work test was also introduced for Food Stamps. This is outside our sample period.

[19] We assume that the means-tested transfer is paid in cash rather than in the form of coupons (as with Food Stamps). While this is in contrast with the reality, it would be of little practical importance if stamps were inframarginal or if there were "trafficking." Moffitt (1989) finds evidence for both phenomena.

where $\overline{T}$ is the maximum payment and where $\underline{y}$ should be interpreted as a poverty line. In the actual Food Stamp program, only people with net earnings below the poverty line are eligible for benefits (which we denote by $E_{it}^{T} = 1$). The maximum value of the payment, $\overline{T}$, is set assuming a household with two adults and two children, although in our model there is only one earner.

Disability Benefits and Social Security.—Workers may find themselves in circumstances that would lead them to apply for disability insurance, the final element of the budget constraint. First, we allow only individuals who face a negative productivity shock to apply for disability. The requirement of a negative shock to wages is meant to mimic a health shock, on the basis of which an individual could claim to be eligible. Second, we require people to remain unemployed for at least one quarter before being able to apply for disability insurance, and then they must remain unemployed in the quarter in which the application is made. Again, this is meant to reflect the actual rules of the system: there is a waiting period of five months between application and receipt of benefits, and during this period the individual must be unemployed. Third, we assume that only workers above the age of 50 are eligible to apply for disability benefits.[20]

Conditional on applying, individuals have a fixed probability of obtaining the benefit, which we obtain from actual data (50 percent, see John Bound et al. 2004). If successful, the individual remains eligible for the rest of his working life, and disability insurance becomes an absorbing state. If not successful, the individual has to remain unemployed another quarter before taking up a job. Individuals can reapply only in a subsequent unemployment spell. The combination of disability and the means-tested program turns out to be very important in fitting the decline in employment with age. Disability payments can provide a high replacement rate which is not affected by the duration of unemployment. However, the requirement that individuals spend two quarters unemployed before the disability application is resolved would discourage a large proportion of applicants were it not for the means-tested (Food Stamps) program, which provides a floor to income during this application process.

The value of disability insurance is given by

$$(6) \quad D_{it} = \begin{cases} 0.9 \times \overline{w}_i & \text{if } \overline{w}_i \leq a_1 \\ 0.9 \times a_1 + 0.32 \times (\overline{w}_i - a_1) & \text{if } a_1 < \overline{w}_i \leq a_2 \\ 0.9 \times a_1 + 0.32 \times (a_2 - a_1) + 0.15 \times (\overline{w}_i - a_2) & \text{if } a_2 < \overline{w}_i \leq a_3 \\ 0.9 \times a_1 + 0.32 \times (a_2 - a_1) + 0.15(a_3 - a_2) & \text{if } \overline{w}_i > a_3 \end{cases}$$

where $\overline{w}_i$ is average earnings computed before the time of the application and a_1, a_2, and a_3 are thresholds we take from the legislation. We assume $\overline{w}_i$ can be approximated by the value of the permanent wage at the time of the application. Whether an individual is eligible (i.e., $E_{it}^{DI} = 1$) depends on the decision to apply ($DI_{it} = 1$) while being out of work, on having received a large negative productivity shock, and on the application being successful. We assume that the probability of success is independent of age. Eligibility does not depend on whether an individual quits or the job is destroyed.

By contrast with our assumption of a 50 percent probability of success for DI is our assumption of 100 percent take-up for our universal means-tested program and for unemployment insurance. We assume that this difference arises because of the difficulty of verifying disability compared to the income test and the unemployment test.

In retirement, all individuals receive Social Security calculated using the same formula used for disability insurance.

[20] Interestingly, this was an actual requirement of the program at the time of inception (1956). In our model, it reflects the fact that health shocks triggering disability are rare before this age.

E. *Employment Risk and Wage Risk*

We allow for different types of shock that constitute risk an individual is facing, and we distinguish earnings and employment fluctuations driven by endogenous decisions versus unexpected shocks. The direct shocks to wages are interpreted as productivity risk. The job destruction process, the rate at which job offers are sampled in and out of work, and the heterogeneity of firms constitute employment risk.

The distinction between employment and wage risk becomes relevant in the presence of search frictions and is further reinforced by the probability of job destruction. Firm heterogeneity adds another dimension to this risk: it means that some jobs may be available with a match value that would lead to a wage worth taking for an unemployed individual, even following a very bad productivity shock. Search frictions, however, make it hard to find such a job and create uncertainty in both the length of unemployment and in prospective earnings. Moreover, firm heterogeneity generates an option value to waiting in the unemployment state if the job arrival rate when on the job is lower than the job arrival rate when unemployed. The model allows us to identify the effects of changes in each of these risks from the behavioral reactions to their presence/change.

The productivity shocks that we observe are assumed to be uninsurable uncertainty. These productivity shocks may, for example, reflect health shocks or demographic shocks, but we do not specify their source in this model. We assume that there is no commitment from the side of the firm (or the worker), so Milton Harris and Bengt Holmstrom (1982)–type contracts are not implementable. Further, we assume there is no private insurance market against employment risk. This incomplete markets set-up is consistent with results from Attanasio and Davis (1996) and others.[21]

F. *Value Function and Model Solution*

The solution of the model consists of policy functions for consumption, the decision to work, and realizations of earnings, career paths, assets, etc. There are no analytical expressions for these. Instead, the model must be solved numerically, beginning with the terminal condition on assets and iterating backwards, solving at each age for the value functions conditional on work status. In this section we discuss the key features of the solution. More details on the method are provided in online Appendix A http://www.aeaweb.org/articles.php?doi=10.1257/aer.100.4.1391.

For those employed, the state variables are $\{A_{it}, u_{it}, a_{ij(t_0)}\}$, corresponding to current assets, individual productivity, and the match effect. The match effect is indexed by t_0, which is the date the job began.[22] For the unemployed and not on disability, the state variables are $\{A_{it}, u_{it}, DI_t^{Elig}\}$, corresponding to current assets, individual productivity and an indicator of whether the individual is eligible to apply for disability in that period. For those unemployed and receiving disability, the state variables are $\{A_{it}, D_{it}\}$ where D_{it} is the amount of disability benefit received defined by equation (6). Consumption is chosen to maximize each value function conditional on all other

[21] It is possible that observed wages may have already been smoothed out relative to productivity by implicit agreements within the firm. This means that productivity risk may be greater than observed wage movements within a firm, which implies that the process for productivity shocks is not properly identified for the unemployed. In other words, productivity shocks are a combination of actual shocks plus insurance, but this insurance is present only if the individual is working. If the unemployed experience greater productivity risk than estimated, this will impact on the reservation wage and on job search. For the time being we ignore this issue as far as permanent shocks are concerned.

[22] Ideally we should model the behavior of the firm. If the firm has a fixed number of positions, and if there are firing costs, a firm with characteristic $a_{ij(\cdot)}$ may not make an offer to any worker. High $a_{ij(\cdot)}$ firms may wish to wait to locate high u_{it} workers, in the same way that high u_{it} workers may wish to wait for high $a_{ij(\cdot)}$ firms. At present we ignore this issue.

decisions. Once consumption is substituted out of each value function the discrete labor supply and mobility decisions can be made.

The value function for an employed individual incorporates the fact that in the next period he will have the choice of quitting into unemployment, moving to a new job if he gets an alternative offer or staying with the firm. However, if the job is destroyed, the individual will have to move to unemployment. Thus the value function for an individual i who is working in period t is

$$
\begin{aligned}
(7)\quad & V_t^e(A_{it}, u_{it}, a_{ij(t_0)}) \\
&= \max_c \Big\{U(c_{it}, P_{it} = 1) + \beta\delta E_t\big[V_{t+1}^n\big(A_{it+1}, u_{it+1}, DI_{it+1}^{Elig} = 1\big)\big] \\
&\qquad + \beta(1-\delta)(1-\lambda^e)\, E_t\Big[\max\Big\{V_{t+1}^n\big(A_{it+1}, u_{it+1}, DI_{it+1}^{Elig} = 1\big), V_{t+1}^e(A_{it+1}, u_{it+1}, a_{ij(t_0)}),\Big\}\Big] \\
&\qquad + \beta(1-\delta)\lambda^e E_t\Big[\max\Big\{V_{t+1}^n\big(A_{it+1}, u_{it+1}, DI_{it+1}^{Elig} = 1\big), \\
&\qquad\qquad V_{t+1}^e(A_{it+1}, u_{it+1}, a_{ij(t_0)}), V_{t+1}^e(A_{it+1}, u_{it+1}, a_{ij(t+1)})\Big\}\Big].
\end{aligned}
$$

The expectation operator is conditional on information at time t. If there is no offer available in $t+1$, the expectation operator is over the productivity shock only; if an offer is available in $t+1$, the expectation taken in t is also over the type of firm making the offer.

Among the unemployed, we distinguish between those who have the option of applying for disability and those who are ineligible to apply (either because the individual is under 50, because he has not had a negative productivity shock, or because he has had an application turned down in the current unemployment spell).

For an individual who is eligible to apply for disability, the value function is given by

$$
(8)\qquad V_t^n(A_{it}, u_{it}, DI^{Elig} = 1) = \max_{c, Apply}\left\{u(c_{it}, P_{it} = 0) + \beta\begin{cases} V_{t+1}^A & \text{if } Apply = 1 \\ V_{t+1}^{NA} & \text{if } Apply = 0 \end{cases}\right\}
$$

where

$$
\begin{aligned}
V_{t+1}^{NA} &= \lambda^n E_t\big[\max\big\{V_{t+1}^n(A_{it+1}, u_{it+1}, DI^{Elig} = 1), V_{t+1}^e(A_{it+1}, u_{it+1}, a_{ij(t+1)})\big\}\big] \\
&\quad + (1-\lambda^n)E_t\big[V_{t+1}^n(A_{it+1}, u_{it+1}, DI^{Elig} = 1)\big] \\
V_{t+1}^A &= S \times V_{t+1}^{DI}(A_{it+1}, D_{it+1}) + (1-S) \times E_t\big[V_{t+1}^n(A_{it+1}, u_{it+1}, DI^{Elig} = 0)\big]
\end{aligned}
$$

and S is the exogenous probability of a successful application. When deciding whether or not to apply, the individual already knows if he has a job offer in that period. If the disability application is successful, we can calculate the resulting value function, V_{t+1}^{DI}, analytically: the amount of the disability insurance payment, D_{it}, depends on the permanent wage only and not on the particular firm that the individual has most recently been working for. This amount is earned each year until retirement.

Based on a comparison of the value functions, in each period the individual decides whether or not to work; and if working, whether or not to move to another job if the opportunity arises; and if not working, whether or not to apply for disability benefit. The decision about whether or not to move to another job if an outside offer is received is, in practice, more straightforward than the other decisions because we assume that there is no cost of switching firm. This means that the decision to switch firm involves a simple comparison of the $a_{ij(\cdot)}$, and the individual will move if the new offer is from a higher $a_{ij(\cdot)}$ firm than the current one.[23]

Because of the discrete nature of labor supply, consumption may not be continuous in assets, and value functions may not be necessarily differentiable, which complicates the optimization problem. See online Appendix A for a discussion of these issues.

II. Data

We use the 1993 panel of the Survey of Income and Program Participation (SIPP) to estimate our wage dynamics parameters because it records all job-to-job transitions and the resulting new wage each time. However, the SIPP follows individuals for only three years, and this means that it is less useful for duration analysis. We use the 1988–1996 Panel Study of Income Dynamics (PSID) to construct employment and unemployment duration profiles. In both datasets, we stratify the sample by education, low (those with a high school diploma or less), and high (those with some college or more).

A. *The SIPP*

The main objective of the Survey of Income and Program Participation (SIPP), conducted by the US Census Bureau, is to provide accurate and comprehensive information about the income and welfare program participation of individuals and households in the United States. The SIPP offers detailed information on cash and non-cash income on a subannual basis. The survey also collects data on taxes, assets, liabilities, and participation in government transfer programs.

The SIPP is a nationally representative sample of individuals 15 years of age and older living in households in the civilian noninstitutionalized population. Those individuals, along with others who subsequently come to live with them, are interviewed once every four months for a certain number of times (from a minimum of three to a maximum of 13 times). Each year, a new panel starts, so some overlapping is expected. The first sample, the 1984 Panel, began interviews in October 1983 and surveyed individuals nine times. The second sample, the 1985 Panel, began in February 1985 and surveyed individuals eight times. We use the 1993 Panel, which has nine interviews in total (or 36 months of data for those completing all interviews).[24]

The Census Bureau randomly assigns people in each panel to four rotation groups. Each rotation group is interviewed in a separate month. Four rotation groups thus constitute one cycle, called a wave, of interviewing for the entire panel. At each interview, respondents are asked to provide information covering the four months since the previous interview. The four-month span is the reference period for the interview.

Our sample selection is as follows. The raw data have 62,721 records, one for each member of the survey households, corresponding to 1,767,748 month/person observations (note that, due to attrition, not all individuals complete nine interviews). We drop females, those aged below 22 or above 61, those completing fewer than nine interviews, the self-employed, those who are recalled by their previous employer after a separation, those with missing information about the

[23] If we were to allow for a cost of switching firm in the numerical solution, then the decision about whether or not to switch would depend on a comparison of the value function at the existing firm and the value function at the new firm. This difference will depend on the expected duration of the new job, the worker's horizon, and all elements of the dynamic programming problem.

[24] The raw data can be obtained at http://www.nber.org/data/sipp.html.

state of residence, and those with outlier earnings.[25] Our final sample includes 6,494 individuals corresponding to 233,784 month/person observations. We report some sample statistics in Table 7 in online Appendix C.

Our measure of (firm-specific) hourly wage is obtained by dividing annual earnings earned at the firm by annual hours worked at the firm.[26] Individuals may have multiple hourly wage observations within a year if they work for multiple firms (concurrently or not). We use only the main job (the one that pays the highest proportion of annual earnings). In the SIPP, each firm an individual is working for is assigned an ID.[27] We set $M_{it} = 1$ if the employer the individual is working for at time t is different from the one he was working for at time $t - 1$. We allocate individuals to the low and high education groups based on response to a question about the highest grade of school attended. An important advantage of the SIPP over the PSID when it comes to estimating the wage process allowing for job mobility is that the SIPP does not average pay over different employers. Thus the full effect of a move from one employer to another is observed.

B. *The PSID*

The PSID data are drawn from the 1988–1996 family and individual-merged files.[28] The PSID started in 1968 collecting information on a sample of roughly 5,000 households. Of these, about 3,000 were representative of the US population as a whole (the core sample), and about 2,000 were low-income families (the Census Bureau's SEO sample). Thereafter, both the original families and their split-offs (children of the original family forming a family of their own) have been followed. In the empirical analysis we use the heads of the core sample households after 1988 because detailed data on monthly employment status and other variables of interest are available only after that year and only for household heads.

Our sample selection is as follows. As with the SIPP, we focus on working-age males, aged 22–61. We drop those with missing records on education and the monthly employment status question, and the self-employed. Education level is computed using the PSID variable with the same name.

The PSID asked individuals to report their employment status in each month of the previous calendar year and their year of retirement (if any). We use these questions to construct a quarterly employment indicator for each individual and the duration of unemployment spells. We classify as not employed in a given month those who report to be unemployed/temporarily laid off, out of the labor force, or both, in that month. We treat unemployment and out-of-labor-force as the same state; this tallies with the definition of unemployment that we use in the simulations (see Christopher J. Flinn and Heckman 1983 for a discussion of the difference between these two reported states).[29] In principle, the durations are both left- and right-censored. Some spells begin before the time of the first interview, while some spells are still in progress at the time of the last interview. To avoid problems of left-censoring we use only spells that begin in the sample and drop those with less than three years of data. In calculating durations, we take our sample to be individuals who exit between 1988 and 1992. However, we

[25] An outlier is defined as one whose annualized earnings fall by more than 75 percent or grow by more than 250 percent. This is not influenced by periods of unemployment.

[26] The average hourly wage data refer to 1993, 1994, and 1995. Due to the rotating nature of the 1993 SIPP panel, there are some individuals who report wage data for one, two, or three months in 1992. We do not use these data because they may not be informative about wages over the entire year.

[27] We use corrected firm IDs (see Stinson 2003).

[28] The raw data are available at http://psidonline.isr.umich.edu/.

[29] If the distinction in the data between out-of-labor-force and unemployment reflects a difference in search intensity, we could make a meaningful distinction in our model only if we introduced a search decision with a cost attached.

use more recent years of PSID data (1993–1996) to calculate durations for those whose spells are right-censored by the 1988–1992 window. This reduces the censoring from 13.09 percent of all spells to 5.29 percent.

III. Estimating the Wage Process

In estimating the wage process, we take the difference of the wage equation (1) between years.[30] Taking the process for permanent shocks (2) and recalling that $\xi_{it} = (a_{ij(t)} - a_{ij(t_0)})$, we obtain:

$$\Delta \ln w_{it} = \Delta d_t + \Delta x_{it}' \psi + \zeta_{it} + \Delta e_{it} + \xi_{it} M_{it}$$

where the indicator M_{it} is one for those who changed employer and zero otherwise. Wage growth is observed only for those who work in both periods. If one were to ignore selection issues, under the assumptions discussed in Section IB the variance of the permanent shock to wages can be estimated using the residual *within*-firm wage growth $g_{it,w} = \zeta_{it} + \Delta e_{it}$ based on the expression $\sigma_\zeta^2 = E(g_{it,w}^2) + 2E(g_{it,w} g_{it-1,w})$, where the subscript w denotes "within." The measurement error variance is recovered by $\sigma_e^2 = -E(g_{it} g_{it-1})$ using data for the whole sample of workers. Finally, the variance of the match effect can then be estimated based on the variance of residual wage growth between firms $g_{it,b} = \zeta_{it} + \Delta e_{it} + a_{ij(t)} - a_{ij(t_0)}$ using the expression $\sigma_a^2 = 1/2(E(g_{it,b}^2) - \sigma_\zeta^2 - 2\sigma_e^2)$, where the subscript b denotes "between."

However, selection issues are central in our model: wages are observed conditional on individuals working; within-firm wage growth, which identifies the variance of permanent productivity shocks, is observed only if the individual does not change jobs; between-firm wage growth, which helps identify heterogeneity across firms, is observed only for job movers. Further, employment and mobility decisions are all endogenous, and if this is ignored we risk biasing the estimates of the variances to wages and of firm heterogeneity.

To address this problem our approach is as follows: first we model the selection process into and out of work and between firms. We then construct sample selection terms and estimate wage growth equations conditioning on these terms. We finally obtain the estimates of the variances of interest by modeling the first and second moments of unexplained wage growth for various subgroups.

Define the latent utility from working as $P_{it}^* = z_{it}' \varphi + \pi_{it}$. The associated labor market employment index is $P_{it} = 1\{P_{it}^* > 0\}$, which is unity for workers. Workers separate from their current employer voluntarily (quits) or involuntarily (layoffs). As argued by George J. Borjas and Sherwin Rosen (1980), job turnover, regardless of who initiates it, represents the same underlying phenomenon, that of workers' marginal product being higher elsewhere. Let $M_{it}^* = k_{it}' \theta + \mu_{it}$ denote the latent utility from moving in period t to an employer that is different from the one in $t-1$. We have that $M_{it} = 1\{M_{it}^* > 0\}$. We assume: $(\pi_{it} \ \pi_{it-1} \ \mu_{it})' \sim N(\mathbf{0}, \mathbf{I})$ and serially independent. Selection into and out of work and into new jobs is accounted for by the correlations between π_{it} and $\zeta_{it}(\rho_{\zeta\pi})$, π_{it} and $\xi_{it}(\rho_{\xi\pi})$, π_{it} and $\xi_{it-1}(\rho_{\xi\pi-1})$, μ_{it} and $\zeta_{it}(\rho_{\zeta\mu})$, and μ_{it} and $\xi_{it}(\rho_{\xi\mu})$.

[30] To smooth the effect of the well-known seam bias in the SIPP, in our estimation procedure we focus on annual wage growth rather than quarterly growth. In online Appendix B we discuss how the timing involved in our estimation procedure is reconciled with the model.

Suppose now that we select only those who work at t and $t - 1$ ($P_{it} = 1$ and $P_{it-1} = 1$). It is easy to show that:

$$(9)\ E(\Delta \ln w_{it} | P_{it} = 1, P_{it-1} = 1)$$
$$= E(\Delta \ln w_{it} | P_{it} = 1, P_{it-1} = 1, M_{it} = 1) \Pr(M_{it} = 1)$$
$$+ E(\Delta \ln w_{it} | P_{it} = 1, P_{it-1} = 1, M_{it} = 0)(1 - \Pr(M_{it} = 1))$$
$$= \Delta d_t + \Delta x_{it}' \psi + G_{it}$$

where G_{it} is a selection term induced by employment and interfirm mobility (see online Appendix B for details).[31] We estimate the components of this selection term in a first stage by running separate probit regressions[32] and use these to estimate the parameters of (9) consistently in a second stage using only workers in both periods.

We now need to estimate the variance of the permanent shocks, the variance of the firm-level heterogeneity, and the variance of the measurement error. Estimation is based on the moments of unexplained wage growth (observed only for workers in both periods):

$$(10)\qquad g_{it} = \Delta(\ln w_{it} - d_t - x_{it}'\psi) = \zeta_{it} + \Delta e_{it} + \xi_{it} M_{it}.$$

We use the first and second moments of (10) for movers ($M_{it} = 1$) and for stayers ($M_{it} = 0$), as well as the first-order autocovariance, always correcting for selection due to employment and mobility. In addition to the two variances of interest we also estimate the relevant correlations that drive selection. The estimation process takes into account that the wage growth we model is annual, while the work decision is quarterly, in accordance with the model. The details of the entire estimation process are given in online Appendix B.

Standard errors are computed using the block-bootstrap procedure suggested by Joel L. Horowitz (2003). In this way we account for serial correlation of arbitrary form, heteroskedasticity, as well as for the fact that we use a multistep estimation procedure, preestimated residuals, and selection terms. We should point out that this procedure is likely to be conservative, since it allows for more serial correlation than that implied by the moment conditions we use.

A. *Results*

Employment and Mobility.—We start by estimating quarterly probits for employment using the SIPP data. Our regressors include a quadratic in age, a dummy for whites, region dummies, a dummy for married, year dummies, as well as unearned household income and an index of generosity of the welfare system, which here we proxy with the generosity of the state-level UI system.[33] The latter two are excluded from the wage equation and are the instruments that identify selection

[31] In estimation we do not use the restrictions on the parameters of interest imposed by (9). This results only in a loss of efficiency, but it does not affect consistency. We estimate the standard errors by the block bootstrap.

[32] The assumed orthogonality assumption between π_{it} and μ_{it} allows us to do this.

[33] Unearned household income is defined as total household income net of household earnings and means-tested cash benefits. To obtain a measure of the generosity of the UI program in the state where the worker lives, we rank states according to the maximum weekly UI benefit (which we take from current legislation). Our measure of generosity is the rank variable, which varies over time and across states. We obtain similar results if we rank states pooling data for all years. Ideally, one would like to use an index of generosity of the Food Stamps program, but this is a federal program and its time-series variability is negligible.

into work—the unearned income as a pure income effect and the generosity of the UI system as a fixed cost of work.[34] The probit estimates for each quarter are reported in online Appendix C, Table 8. The main point is that unearned income has a strong and significantly negative effect on the probability of working. The generosity of the UI system is also a significant factor discouraging work, but only for the lower education group and not for the college graduates.

We also estimate a mobility probit, which will allow us to control for the censoring of between-firm wage growth. The dependent variable is whether an individual who was working in period t is in a different job in period $t + 1$. Thus for the purposes of this estimation, mobility may include those moving jobs via unemployment. The mobility probit includes the same variables as the employment equation, as well as industry dummies and an indicator as to whether the person was working for a nonprofit organization, in both cases for period t. Unearned income influences mobility positively for both education groups; UI generosity influences mobility positively for the lower education group but not the college graduates. The effect of UI on mobility is theoretically ambiguous. On the one hand, it increases the reservation wage leading to individuals quitting employment following negative wage shocks and increasing mobility through this mechanism. On the other hand, when UI is low, durations of unemployment will be shorter and wage increases will occur through job-to-job mobility; the former effect dominates. Our results also show that mobility declines with age for both groups. This decline arises because of a selection effect: older individuals have had the opportunity to move to jobs with higher match components, and thus it becomes increasingly unlikely that an outside offer is sufficiently good to trigger mobility. Job destruction is an important force disrupting this age effect. Table 9 in online Appendix C presents the results.

Variance Estimates.—Armed with these results, we move on to estimate the parameters of the wage process by the method of moments, imposing constraints across equations. The results are reported in Table 1. The σ parameters refer to the standard deviations of the various stochastic components of wages. The ρ parameters are the correlations between the various stochastic shocks and the shocks driving selection. They are defined in online Appendix B, which also report the moments we fit and the corrections for selection. We estimate the model for the whole sample to have a comparison with previous work (column 1) and separately by the two education groups (columns 2 and 3).

When we control for selection into employment and for job mobility, we find that in the whole sample the standard deviation of the permanent shock, σ_ζ, is about 0.10, the standard deviation of the measurement error, σ_e, 0.09, and the standard deviation of the match-specific effect, σ_a, 0.23. These parameters are all very precisely estimated. They imply that match heterogeneity is a very important component of wage dispersion: wages for the same individual drawing different match components could vary by as much as ± 46 *percent* (i.e., $\pm$ two standard deviations) with a probability of 95 percent.

Columns 2 and 3 report the results of estimating the model separately for our two education groups. There are some differences in the stochastic process of wages of the two education groups. For example, the high educated face a higher variance of the permanent shock than the low educated.

What happens if we ignore the fact that mobility is endogenous and attribute all wage fluctuations to the permanent and transitory shocks (σ_ζ and σ_e)? This, implicitly, has been the assumption

[34] We exploit variation over states and time that exists in the generosity of the UI system. For this exclusion restriction to be valid the US labor market should be sufficiently integrated, and sufficient trade should be taking place, so that variability in benefits in one state does not affect wage in that state. For the unearned income exclusion restriction to be valid requires that UI payments do not affect wages through bargaining, as in Christopher A. Pissarides (2000), or through compensating differentials, as in Topel (1984). Our model imposes the weaker condition that these instruments can be excluded from *wage growth*.

Table 1—Wage Variance Estimates

	Whole sample (1)	Low education (2)	High education (3)	Neglect mobility (all) (4)
Standard deviations				
σ_ζ	0.103	0.095	0.106	0.152
	(0.012)	(0.022)	(0.017)	(0.009)
	[0%]	[1%]	[0%]	[0%]
σ_e	0.087	0.084	0.088	0.086
	(0.011)	0.035)	(0.016)	(0.005)
	[0%]	[0%]	[0%]	[0%]
σ_a	0.228	0.226	0.229	
	(0.011)	(0.019)	(0.015)	
	[0%]	[0%]	[0%]	
Correlations				
$\rho_{\zeta\pi}$	0.153	0.214	−0.104	0.509
	(0.244)	(0.254)	(0.293)	(0.171)
	[40%]	[22%]	[74%]	[1%]
$\rho_{\zeta\mu}$	−0.847	−0.990	−0.871	
	(0.410)	(0.469)	(0.498)	
	[0%]	[0%]	[0%]	
$\rho_{\xi\pi}$	−0.036	0.164	0.149	
	(0.351)	(0.417)	(0.402)	
	[43%]	[91%]	[8%]	
$\rho_{\xi\pi-1}$	0.190	−0.071	0.190	
	(0.239)	(0.254)	(n.a.)	
	[4%]	[99%]	[n.a.]	
$\rho_{\xi\mu}$	0.324	0.353	0.333	
	(0.165)	(0.202)	(0.216)	
	[0%]	[2%]	[1%]	

Notes: σ_ζ, σ_e, and σ_a are the standard deviations of the permanent shock, measurement error, and the match component. $\rho_{\zeta\pi}$ ($\rho_{\xi\pi}$) is the correlation between the permanent shock (mobility premium $\xi = a_j - a_{j-1}$) and unobserved heterogeneity in the employment equation. $\rho_{\xi\pi-1}$ is the correlation between the mobility premium and unobserved heterogeneity in the employment equation in the previous period. $\rho_{\zeta\mu}$ ($\rho_{\xi\mu}$) is the correlation between the permanent shock (mobility premium) and unobserved heterogeneity in the mobility equation. Standard errors (in parentheses) are computed using the block bootstrap (400 replications). Bootstrap *p*-values in square brackets. We constrain all the correlation coefficients to lie between minus 1 and 1. In column (3) we set $\rho_{\xi\pi-1}$ to the whole sample estimate due to convergence problems.

made in papers estimating the covariance structure of earnings (MaCurdy 1982; Abowd and Card 1989; Meghir and Pistaferri 2004) and in the precautionary savings papers estimating risk via the standard transitory/permanent shock decomposition (Carroll and Samwick 1997; Gourinchas and Parker 2002). In column 4 we report the results of this experiment for the whole sample. The estimated standard deviation of the permanent shock σ_ζ increases by about 50 percent: a large proportion of wage fluctuations usually attributed to unexpected shocks is in fact a result of endogenous mobility choices. This is likely to be important for the welfare costs of risk because individuals change jobs quite frequently and because they do not have to accept worse-paying jobs than the one they have. However, match dispersion does itself introduce risk: first because individuals with good matches who are displaced can expect to be hired at a lower rate (on average); and second, because individuals face uncertainty about the quality of offers they are likely to receive. On the other hand, match dispersion also offers the possibility of job improvements, which as we shall see is a dominant factor in the effect of such dispersion on welfare when the arrival rate is sufficiently high.

Table 2—Parameters Obtained through Calibration

Parameter	High education	Low education
Job destruction rate δ	0.028	0.049
Job arrival rate—unemployed λ^n	0.82	0.76
Job arrival rate—employed λ^e	0.72	0.67
Fixed cost of work F	\$1,213	\$1,088
Disutility of working η	-0.62	-0.55

Notes: The values of δ , λ^n, and λ^e are given as quarterly rates. The value of the fixed cost F for each education group is per quarter.

The estimated correlations that drive selection are reported in the lower panel of Table 1 and conform to the expected signs. The most significant is the negative correlation between the permanent shock and mobility $(\rho_{\zeta\mu})$. For the purposes of correcting for selection in estimation, mobility is defined as any job change, including those taking place through unemployment. Since a good productivity shock will encourage people to work, it will also result in fewer job changes than otherwise—hence the negative and significant correlation. The next most important one, with an overall p-value below one percent is, the correlation between a good alternative offer and mobility, which is positive and quite large, as expected.

IV. Calibrated Parameters

We now need to set the remaining parameters required to complete the model. We set the coefficient of relative risk aversion γ equal to 1.5, taken from Attanasio and Weber (1995), whose model of consumption also allows for nonseparable labor supply. The real interest rate is set equal to the real return on three-month treasury bills, at an annual rate $r = 0.015$, and this is set equal to the discount rate $((1/\beta) - 1)$. The remaining parameters we obtain through calibration using the structural model outlined in Section I.

Given the estimated parameters of the wage process and those set above, we now set the remaining parameters to fit the life-cycle employment profile and unemployment duration profile for men, by education group. Our approach is to choose the parameters for each education group to minimize the absolute distance between statistics calculated in the data and corresponding simulated statistics.

The statistics we use are the average employment rate in four ten-year age bands (22–31, 32–41, 42–51, and 52–61) and the mean duration of unemployment in eight five-year age bands. In Table 10 online in Appendix C we show the fit of the moments we have targeted. In Table 2, we present the calibrated parameter values, with job destruction and arrival rates given at quarterly rates. In figures 1 and 2 we show the calibrated profiles.

The job destruction rate is about 75 percent higher for the lower-educated individuals than for the higher-educated ones. The contact rates are higher for the more educated, and they are higher for those out of work than when in work, possibly reflecting increased costs of search when working or different incentives to search in the two states. The value of η for high-education individuals implies that work is equivalent to a 46 percent loss of consumption. For those of low education the equivalent consumption loss is 42 percent.[35] These values also imply that consumption and leisure are substitutes, and thus it is consistent with the observed fall of consumption upon retirement (or unemployment). Finally, the fixed costs of work for both education groups

[35] The consumption equivalent is calculated as $(1 - \exp[\eta])$.

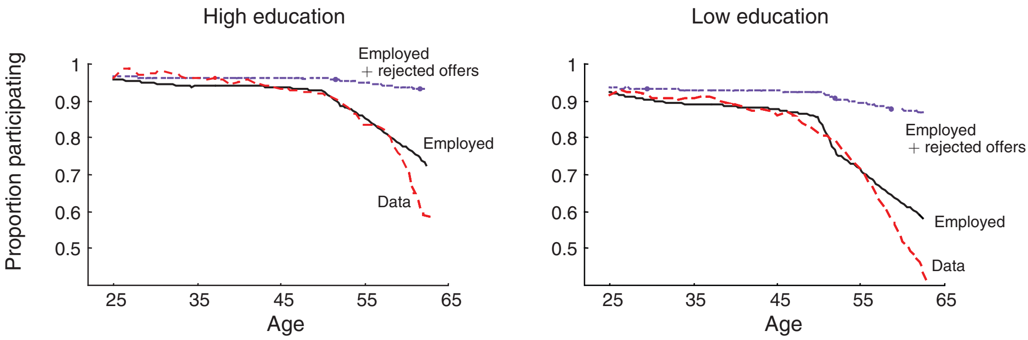

Figure 1. Employment over the Life Cycle

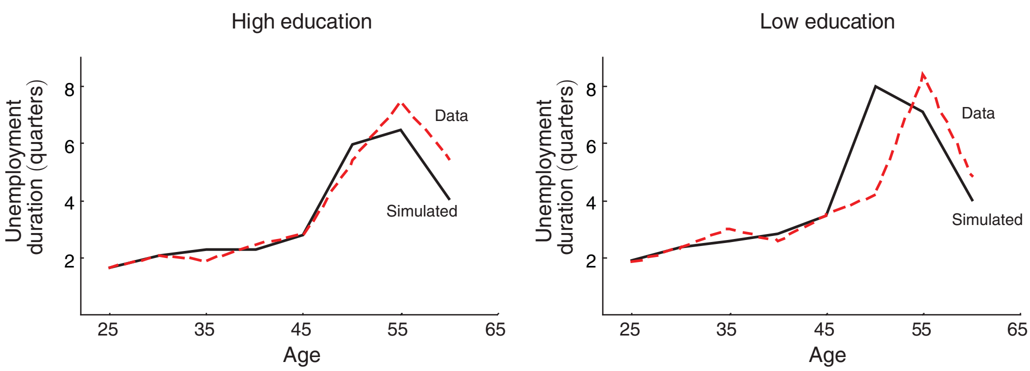

Figure 2. Mean Unemployment Duration over the Life Cycle

are expressed in dollar values per quarter. For the low educated, this corresponds to about $91 per week in 1992 prices, which is equivalent to seven hours a week evaluated at the average wage of those working. For the high educated, the cost is $101, equivalent to about five hours a week. French (2005) estimates the fixed cost in terms of hours, rather than dollars, and his preferred estimate corresponds to a fixed cost of about five hours a week for all workers.

Figure 1 shows employment profiles for the high educated and low educated. Each figure compares the profile in the data with the calibrated profile (labeled "employed").[36] For both education groups, employment rates are constant or display a slow decline until the age of 45, followed by a sharp decline to age 62. Part of this fall reflects early retirement, rather than temporary periods out of the labor force. Since early retirement is an endogenous labor supply response, we treat this in the same way as we treat unemployment. There is a level difference between the two groups: the high educated work more than the low educated up to age 45 (employment rates are around 96 percent, compared to 90 percent for the low educated), and the subsequent decline is less marked. Our match of employment is fairly good for both skill groups.

We also plot the employment rate that would be obtained if all offers received (including those offers from an existing employer) were accepted. Since the offer rate is constant over the life cycle, the downturn in employment with age is due to more offers being rejected.

[36] The profiles from the data are calculated controlling for cohort effects and assuming that time effects average out to zero and are orthogonal to the time trend. The estimated employment rate is equal to the actual rate at age 40.

Figure 2 compares mean unemployment durations over the life cycle in the simulations and in the data for both education groups. Durations have a maximum length determined by the number of quarters until age 62. In the data, durations are measured in months and are expressed as fractions of a quarter. We are able to match very well the durations for the high-education individuals. For the low educated, we simulate a very similar profile to the one in the data but shifted somewhat to earlier ages.

In the model $\lambda^n, \lambda^e, \delta, F$, and η are independent of age and so the age effects that we find in all the simulated profiles can be explained only by endogenous saving and labor supply behavior in response to the budget constraint and the welfare benefit structure: the match in the slope of profiles over the life cycle is not an artefact of age-varying parameters and is a demonstration of the strength of the model. Average unemployment durations increase over the life cycle because of the increase in assets held by the individual, and this counteracts the fact that older individuals have higher wages and thus a greater incentive to work. In addition, as individuals get older the amount of future uncertainty declines, thus reducing the precautionary motive for working (Low 2005).

A. *Implications of the Model*

We have calibrated the model using only employment rates and unemployment duration data, given the preestimated wage process and given an intertemporal substitution parameter from the literature. However, the model has implications for a range of different variables. In particular, we use the model to predict the wage loss associated with a spell of unemployment, the extent of consumption loss on unemployment, the arrival rate of accepted offers, and the ratio of mean wealth over stages of the life cycle to mean life-cycle income. Table 3 reports the model predictions and corresponding statistics, obtained from various different sources of data, for a number of statistics that are not used in the calibration.

The Cost of Displacement.—There is empirical evidence that displaced workers experience earnings losses following job loss. Some authors impute this to exogenous skill depreciation during periods of unemployment (Richard Rogerson and Martin Schindler 2002; Lars Ljungqvist and Thomas J. Sargent 1998). An alternative that is consistent with our model is that wages on reentry may be lower than before job loss because of the loss of a particular good match on entering unemployment. We report in Table 3 the extent of the wage fall on reentry.

For the high educated, wages on reentry are, on average, 20 percent lower than before displacement. For the low educated, the loss is 14 percent. These figures are similar to those found in the literature. In particular, we compare these figures with those reported by Jacobson, LaLonde, and Sullivan (1993) for their nonmass layoff sample (after controlling for time trends). They report that one quarter after displacement, earnings of displaced workers are 19 percent less than before displacement. Finally, one implication of our model is that the displacement costs are likely to be relatively short lived. Indeed, we calculate that one year after the return to work, wages of the low educated are only 6.1 percent below their predisplacement wages; for high educated individuals the figure is 9.1 percent. These figures are very close to the ones we extrapolate from Jacobson, LaLonde, and Sullivan (1993) over a similar time horizon.

Consumption Fall at Unemployment.—Jonathan Gruber (1997) and Browning and Thomas F. Crossley (2001) have explored empirically the consumption loss associated with unemployment. Consumption will be lower in unemployment if the job loss followed a permanent loss in productivity, which implies a life-cycle wealth effect and a lower incentive to work. In addition if there are nonseparabilities between consumption and leisure, as in our model, and leisure is a substitute for consumption, individuals will cut back on consumption as leisure increases.

Table 3—Model Implications

Statistic	Data: High education	Data: Low education	Model: High education	Model: Low education
Mean wage loss[a]				
$\ln w_\tau - \ln w_t$	−0.19		−0.20	−0.14
$\ln w_{\tau+4} - \ln w_t$	−0.076		−0.091	−0.061
Mean consumption loss (age 25–60)[(b)]				
$[(c_{t+1} - c_t)/c_t]/[(y_{t+1} - y_t)/y_t]$	0.56		0.45	0.61
Arrival rate of accepted job offers (age $<$ 40):				
On-the-job			0.034	0.038
From unemployment			0.51	0.45
Fraction of job offers accepted (age $<$ 40):				
On-the-job			0.047	0.057
From unemployment			0.62	0.59
Mean wealth/mean annual income[c]				
Age 30–35	1.58	1.71	0.98	1.44
Age 50–55	7.27	5.13	5.72	5.30
Decomposition of earnings[d]				
Standard deviation of permanent component	0.17	0.20	0.19	0.21
Standard deviation of transitory component	0.12	0.15	0.11	0.16

Notes:

[a] The data numbers for wage loss are taken from Jacobson, LaLonde, and Sullivan (1993). w_t is the wage at displacement, w_τ is the wage at reentry, $w_{\tau+4}$ is the wage 1 year later.

[b] The data numbers for consumption loss are taken from Browning and Thomas F. Crossley (2001).

[c] The wealth data come from the 1994 PSID wealth supplement and include housing wealth and private pension holdings. Mean annual income is defined as average annual household income for heads of household aged 22–62.

[d] Income growth is defined as growth in annual earnings. This is then decomposed into permanent and transitory components by estimating the variance of the growth of earnings, and the autocovariance of growth. For the data, we report results taken from the lower panel of table III in Meghir and Pistaferri (2004). For our lower education group we take a weighted average of the results in the two lower groups in that paper. For the data generated by the simulations, we impose an MA(1) in the levels of the transitory shock, implying an MA(2) for the overall residual earnings growth. This is consistent with the simulated autocovariance of earnings as well as the earnings data in the PSID.

Finally, if individuals are unable to smooth consumption through borrowing against future income, they will also have to cut back more than they otherwise would. Our model contains these three effects, with the source of the income loss being the loss of the match as well as possibly the wealth effect implied by a negative permanent shock; the nonseparability being built into the structure of the utility function; the liquidity constraint being the restriction that assets have to be nonnegative.

In Table 3 we report average consumption loss by education group and compare it to Browning and Crossley (2001).[37] They use data from a Canadian sample that includes many two-earner households; moreover the Canadian welfare system implies different replacement rates. To control for these differences we compare the percentage consumption loss relative to the percentage

[37] Our numbers are not comparable to the Gruber calculation because he uses only food. One would need to inflate his number by dividing it by the marginal budget share for food to get back to a total consumption figure.

income lost following unemployment. Our figures are remarkably close to the Browning and Crossley number, whose comparable figure is 56 percent.[38] We calculate a 61 percent relative loss for the low educated and a 45 percent loss for the high educated. The Browning-Crossley sample contains 70 percent low-educated individuals. So on this score the model fits the facts very well indeed.

Arrival Rate of Offers.—Table 3 reports the arrival rate of accepted job offers among workers and among the unemployed. For workers, the arrival rate of accepted offers is low because workers choose to move only if they receive a better offer than the wage at their existing firm. Among the unemployed a much higher proportion of offers are accepted: the table shows that, among the low educated, 62 percent of offers are accepted by the unemployed, whereas only 4.7 percent of offers are accepted by the employed. The fast movement out of unemployment is not surprising because the offer arrival rate when employed is not much lower than it is for the unemployed, making the option value of unemployment low.

Wealth Accumulation.—Table 3 reports, for individuals aged 30–35 and 50–55, the ratio of average wealth holdings to average annual income. Our model captures fairly accurately the level of wealth holdings of the low educated at both stages of life. For the high educated, the model underpredicts slightly the wealth holdings, but the rate of wealth accumulation is similar.

Variability of Income.—As noted earlier, despite there being no explicit transitory shocks in the wage process, the interaction of job destruction, the participation and mobility decisions, and other components of employment risk generate a permanent/transitory structure in the time series of *earnings* from the model. These have very similar time-series properties to the ones for the PSID reported by Meghir and Pistaferri (2004).[39] As in that paper, the growth of earnings is consistent with a transitory/permanent shock decomposition, with the latter being MA(1) in levels (MA(2) in growth). The estimates of the variances of each component are remarkably similar. Moreover, the MA coefficient for the transitory shock for the high-education group is -0.65, which compares to -0.51 reported in the paper. The low-education MA parameters are, however, a bit further apart with the one from the model being -0.53 and the one estimated from the PSID -0.26.

Wages and Wage Variability.—Figure 3 shows how wages and the cross-section variance of wages evolve over the life cycle for the two education groups. The top line reports the wage profile for those who are working. Average wages increase with age in the model partly due to search leading to changes in the match component, partly due to deterministic growth in productivity (as reflected in the estimated age effects), and partly due to the composition change caused by selection into work. Early in life, much of wage growth is due to search leading to improved matches. This can be seen by the increase in the difference between the path of actual wages and the path of wages net of the match effect. The difference between this latter line and the offered wage profile shows the contribution of selection, which becomes a substantial factor only after the age of 50.

Figure 4 shows how the variance of wages increases over the life cycle (pooled over both education groups). The line labeled "data" reports the actual cross-sectional variance in the SIPP at each age, while the line labeled "predicted age effect" reports the predicted cross-sectional

[38] Their figures are a 14 percent consumption loss and a 25 percent loss in income, which imply the number we report (56 percent).

[39] Lower panel of table III in Meghir and Pistaferri (2004), p.9.

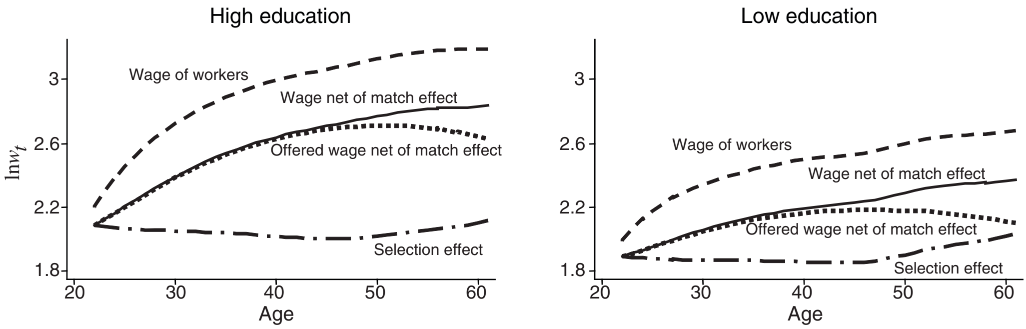

Figure 3. Life-Cycle Wage Profiles

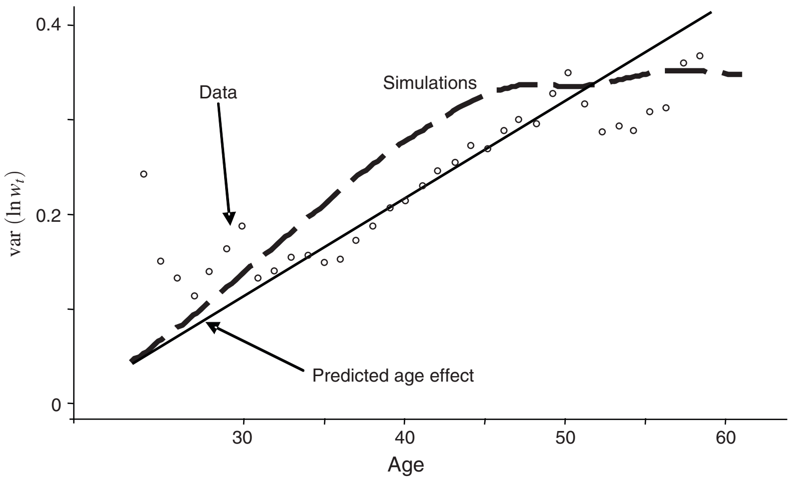

Figure 4. Variance of Wages by Age

variance using the unit root specification for wages assumed in our model.[40] The line labeled "simulations" shows how the cross-section variance of wages for workers in the simulations evolves over the life cycle. The flattening out in the cross-section variance that occurs at older ages in the data and is also observed in the simulations arises because of the sharp decline in participation among men over 50.

V. Evidence on the Wage Process and Alternatives

Our choice of specification for the stochastic process of wages is based on a long and well-established literature. However, this does not make it uncontroversial. In this section, we address

[40] The "estimated age effect" is obtained controlling for cohort effects and assuming that time effects average out to zero and are orthogonal to a time trend.

three issues regarding the specification: first, we consider whether controlling for mobility affects estimates of the persistence of shocks; second, we consider modeling the match component as evolving stochastically over time; finally, we consider introducing heterogeneity in income growth rates, in the way that Guvenen (2009) does.

Mobility and Persistence of Shocks.—One difficulty with relying on the existing literature to support our specification of a unit root in wages is that the papers that provide supporting evidence do not control for worker mobility. In particular, job mobility decisions might create the impression of greater persistence in income: for example, if mobility is ignored, wage increases due to moving firms will be seen as permanent shocks, whereas when we control for mobility, shocks are identified from within-firm wage movements which may be less persistent. Our specification imposes a unit root on within-firm wage movements, but the concern is that wages are not as persistent as they seemed to be when mobility was ignored. To address this, we estimate the autocovariance properties of wage growth residuals for workers who do not change jobs, controlling for selection. These autocovariances still conform to the random walk process, rather than to one with less than unit-root persistence. In particular the autocovariances are statistically and economically insignificant after the first two lags, and there is no evidence of a gradually declining pattern which would have been observed if a simple AR(1) process had generated the data.[41] Thus allowing for mobility cannot account for the earlier finding of a random walk.

Stochastic Match Component.—The analysis in this paper has been based on the assumption that the match-specific effect is constant for the duration of the match and that the shocks to individual productivity persist beyond the current job. In fact, since these shocks are permanent, they persist forever. If we had matched employer-employee data, we could have allowed for a richer specification for the match component. Given our data restrictions, however, the alternative assumption that we explore is that individual heterogeneity is captured by a fixed effect, while the match effect is subject to permanent stochastic shocks.[42]

This specification has a number of interesting implications. First, the shock to the match-specific effect is in effect transitory from an economic point of view: the individual can change jobs following a bad realization of the match effect, thus wiping the slate clean from past shocks even if these are permanent at the match level. This has important implications for the cross-sectional variance of wages by age. In the data, this increases almost linearly with age. We find that our preferred model matches the growth of the variance by age far better than the alternative model, which instead predicts almost a flat profile due to the absence of very persistent economic shocks (see Figure 4).

The second piece of evidence in support of our preferred model comes from the estimates of the variance of initial wages required in the two specifications. Evidence from MaCurdy and Thomas Mroz (1995) and others shows that more recent cohorts face a higher variance on entering the labor market. In our preferred specification the variance of initial wages is indeed higher for more recent cohorts, while in the alternative specification it decreases with year of birth. The reason for the latter is that the only way the alternative model can fit the increasing variance of wages by age that exists in the data is to attribute the increase to cohort effects, i.e., older cohorts have a higher variance on entering the labor market.

[41] We construct an estimate of the wage growth residual in the PSID using the estimates from the SIPP discussed in Section IV. Growth is measured annually. We use the 1987–1992 PSID because it allows us to look at longer autocovariances. In the PSID whether one is a mover or stayer is identified correctly (up to measurement error). For stayers, the autocovariances at lags 0, 1, 2, 3, and 4 are, respectively, 0.0854 (standard error 0.0038), −0.0213 (0.0015), −0.0005 (0.0013), 0.0021 (0.0018), and −0.0029 (0.0030).

[42] The results reported in this section are available in the online Appendix D.

Third, we find that the alternative specification is incapable of capturing the downturn in employment from about age 45 onwards and the increased duration of unemployment spells for older people that is present in the data. This contrasts with the success of our preferred specification. The reason is that with the alternative wage specification anyone quitting due to a negative shock to the match-specific effect can start again with a new job and "wash away" the past. By contrast, when these negative shocks are individual specific and so persist across matches, an individual is more likely to remain unemployed, particularly with the availability of government insurance.

Thus overall, the alternative stochastic specification with the random walk in the match component is not consistent with the data and does not allow the model to match key moments of the data anywhere near as well as we do with our preferred model. This is not to say that a richer model that combined aspects of both stochastic specifications for wages could not do even better. However, given the data limitations, we offer a parsimonious model that is capable of replicating basic features of the data.

Heterogeneous Income Growth Model.—Guvenen (2009) argues that the increase in the cross-sectional variance with age can also be achieved by allowing for heterogeneity in income growth rates (as in Michael Baker 1997), alongside a lower degree of persistence of income shocks (an AR(1) parameter of 0.82). This specification will produce an increase in the cross-section variance of income with age, as in the data and in our preferred specification. If there were less persistence in income shocks but without the income growth heterogeneity, then the variance would be concave in age, and so both components are needed to match the data.

Distinguishing this specification from one with a permanent shock is not straightforward: in the data, the autocovariance of earnings growth is zero for observations more than two or three periods apart, which is consistent with the permanent shock model and not quite in line with the model allowing for an individual-specific fixed effect in growth (the "random growth model"), which would imply nonzero autocovariances at all lags. Guvenen points out that with a high-enough positive autoregressive coefficient the effects of the random growth on the autocovariance structure can be obscured, and its presence can be identified only by considering the covariance of income growth many years apart when the persistent shock has little effect (12 lags or so, see Guvenen 2009). However, long panel datasets have too much attrition over such long time periods to provide a reliable test of this view. A further difficulty with this specification, as pointed out by Guvenen (2007), is that it would not match the growth in the variance of consumption because of the limited innovations to income over the life cycle. In order to match the growth in the variance of consumption when the income process does not have a unit root, it is necessary to assume that individuals do not know their own growth term and have to learn about it over time. This gives rise to innovations over the life cycle leading to an increasing variance of consumption; however, it is difficult to distinguish statistically between learning about a random growth model and learning about a model with a permanent shock.[43] Further, Steven Haider and Gary Solon (2006) suggest that such heterogeneity in trends may be most important early in the life cycle, but that there is little evidence for its importance beyond age 30. Guvenen and Anthony Smith (2008) use consumption and income data to try to separate out the two models. Further, we do not preclude that introducing labor supply choices into a Guvenen framework might generate

[43] Henry S. Farber and Robert Gibbons (1996) assume that individual productivity is unknown to the firm, but it is learned over time through observation of output, and so wages are updated in a Bayesian sense. They prove that this will result in the wage residual being a martingale. Thus our unit-root characterization can also be consistent with a less-than-complete information case, but we have not considered the implications of the learning case as yet.

interesting alternative implications. We have chosen what is a parsimonious specification that fits the data well both in terms of income and in terms of consumption behavior.

VI. The Implications of Risk

Our model and characterization of shocks has important implications for the impact of risk on behavior and welfare. Understanding these is relevant particularly when designing and evaluating policies such as unemployment insurance, food stamps, or other transfers (e.g., tax credits), which effectively insure part of the risk individuals face. In this model, we have exogenous, uninsured idiosyncratic shocks, and so welfare would increase if insurance were provided in a non-distortionary way. We also have behavioral responses to insurance built in both through changes in employment and through changes in savings. This means we can quantify the risk-sharing benefits of different sorts of insurance as well as identifying the behavioral effects induced by the insurance programs.

In this section, we show first the effects of varying productivity risk, looking at the impact on employment, output, and asset accumulation, as well as welfare. We then show the effects of varying the various aspects of employment risk, including job destruction and firm heterogeneity.

In the model the actions of individuals are linked to each other because we require the government budget to balance over the life cycle of a cohort, which is assumed to have N members. Thus we impose

$$\sum_{i=1}^{N}\sum_{t=1}^{T}\frac{1}{R^t}\left[(B_{it}E_{it}^{UI}(1 - E_{it}^{DI}) + D_{it}E_{it}^{DI})(1 - P_{it}) + E_{it}^{T}T_{it}\right] = \sum_{i=1}^{N}\sum_{t=1}^{T}\frac{1}{R^t}\tau_w w_{it} h P_{it} + \mathit{Deficit} \tag{11}$$

where B_{it} is unemployment insurance, D_{it} is disability insurance, and T_{it} is food stamps; E_{it}^{UI}, E_{it}^{DI}, and E_{it}^{T} are $1/0$ indicators of recipiency for each of the programs, respectively, and $P_{it} = 1$ denotes employment. On the right-hand side $\tau_w w_{it} h P_{it}$ represents tax revenue from a working individual. The deficit term represents unaccounted expenditures or revenues and will be kept constant across all simulation experiments. Following a simulated policy change we select the tax rate τ_w to satisfy this government budget constraint; individuals take τ_w as given.[44] Budget balance is imposed *within* a particular education group. We therefore abstract from the insurance *between* groups that Attanasio and Davis (1996) found to be important. Allowing the budget to balance over all education groups would confound the issue we are considering with distributional questions.

To define the welfare cost of risk, write the lifetime expected utility of an individual as

$$E_0 U_k = E_0 \sum_t \beta \frac{(c_{kt}\exp\{\eta P_{kt}\})^{1-\gamma}}{1 - \gamma}$$

where the subscript k refers to the implied consumption and labor supply stream in the baseline economy ($k = 1$) or an alternative economy with different risk characteristics ($k = 2$), and E_0 is

[44] We assume that unemployment insurance and disability insurance are financed by the tax on wages, even though in reality the financing is partly imposed upon the firms. However, if the incidence of the tax falls on the workers, as most empirical studies find, our assumption is inconsequential.

the expectation at the beginning of working life. Now define π as the proportion of consumption an individual is willing to pay to be indifferent between environment $k = 2$ and $k = 1$. This is implicitly defined by

$$E_0 U_2|_{\pi} \equiv E_0 \sum_t \beta \frac{((1 - \pi)c_{2t} \exp\{\eta P_{2t}\})^{1-\gamma}}{1 - \gamma} = E_0 U_1,$$

which implies that $\pi = 1 - [E_0 U_1 / E_0 U_2|_{\pi=0}]^{1/1-\gamma}$.

Since there are no aggregate shocks in the economy and no business-cycle fluctuations, we do not consider the value of, for example, smoothing the effect of the business cycle (as in Lucas 1987) or the value of removing variation in the extent of idiosyncratic risk over the life cycle (as in Storesletten, Telmer, and Yaron 2001). Such insurance removes heteroskedasticity, but the average level of risk remains. Thus we focus entirely on the cost to the individual of idiosyncratic risk, which would be insured in a first best setting.

A. *Wage Risk*

We start by considering the impact of the permanent shock to wages. We have already shown that allowing for job mobility substantially reduces the amount of risk that we attribute to unexpected changes in productivity. Indeed this reduction is likely to be very important.

In Figure 5 we report π, the willingness to pay to avoid changes in risk relative to the estimated baseline.[45] This willingness to pay arises because individuals are averse to the greater risk associated with increases in σ_ζ. Note that when we change the risk faced by the individual many aspects of behavior will change, including labor supply as well as unemployment and employment durations. These will result in output changes, which we also show on the graph, labeled as $\Delta \ln y$. The willingness-to-pay parameter has factored in all these aspects. While changes in wage risk end up implying relatively low changes in output (particularly for the higher educated), they imply large welfare losses. Thus a 50 percent increase of σ_ζ to 0.159 for the high-educated individuals implies a 3.7 percent loss in output but a willingness to pay to avoid this increase of 19.2 percent of consumption (the numbers are in Table 4). It is not straightforward to compare across education groups because the baseline is different. However, we note that if we increase the variance for the low educated to the same level (0.159), welfare goes down by less (16.4 percent). This is partly due to the effect of the welfare programs, which are more important for this lower wage group. Output declines by more for the low educated, as is visible from the graph, driven by the decrease in employment shown in Figure 6. However, the overwhelming impression here is that wage risk is a major determinant of welfare, well beyond its impact on output, making insurance for such risk potentially very valuable.

More detail on the effects of varying wage risk is provided in Table 4: productivity shocks have substantial effects on unemployment durations, on consumption growth, and on rates of asset accumulation, particularly among the young.[46] In particular, for the high-educated group, as σ_ζ increases by 50 percent, the median rate of wealth accumulation for individuals aged 25–35 almost doubles. The resulting wealth effect implies assets peak earlier and then deccumulate faster, as can be seen with the negative asset growth associated with the higher σ_ζ for the older

[45] In all our counterfactual experiments we hold constant the job arrival rates, the job destruction rates, and the implicit pay policy of the firm that determines in equilibrium how the match surplus is shared between workers and the firm. These could all change and could be endogenized in an extension of our model.

[46] If, in addition to the decision of whether or not to work, hours of work were flexible, individuals would be able to self-insure to a greater extent than in our model.

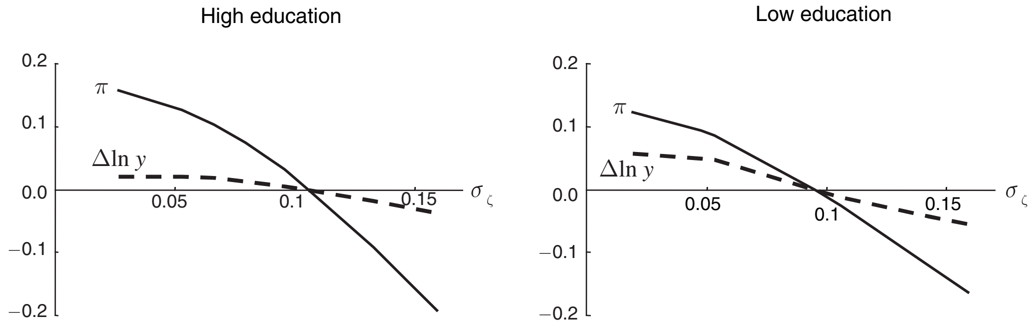

FIGURE 5. WELFARE COSTS AND OUTPUT EFFECTS OF VARYING σ_ζ

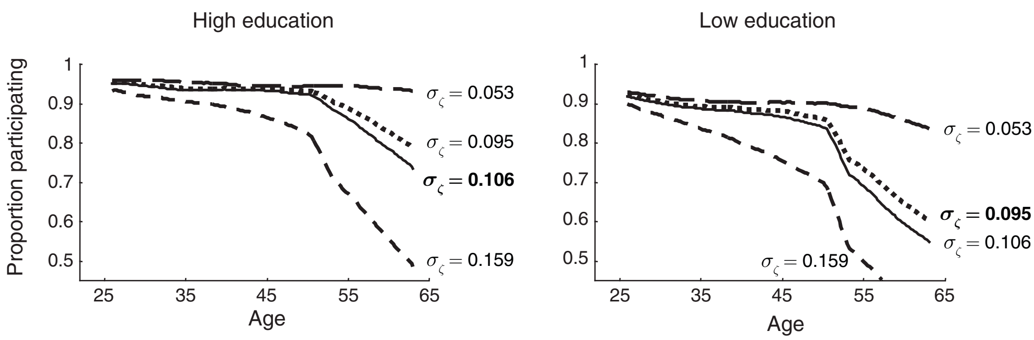

FIGURE 6. EFFECT ON EMPLOYMENT OF VARYING σ_ζ

individuals. The wealth effect is also related to lower employment rates and longer unemployment durations. Table 4 also reports the implications for the standard deviation of annualized earnings growth. The changes in the permanent variance have a somewhat muted effect on the variance of earnings growth.

B. *Employment Risk*

The two important parameters associated directly with employment risk are job destruction and the variance of the match-specific effect. We now consider the implications of varying each of these parameters.

Job Destruction.—Figure 7 shows the impact on welfare and output of varying job destruction, δ. Increases in job destruction have large effects on output partly through increasing unemployment and partly through limiting the time that individuals are matched with the best firms. Individuals are willing to pay to avoid the increase in job destruction. There are three aspects to this willingness to pay: there is a loss of income reflected in the overall loss in output; there is an increase in employment risk; and there is an offsetting increase in leisure time. For both education groups, the effect of the increased riskiness, which otherwise would have raised the welfare loss above the loss of output, is offset by the value of increased leisure resulting from the fall in employment shown in Figure 8. More details of the effects of varying δ on behavior are provided in Table 11 of the online Appendix. There it is shown that increasing δ from 0.1 to 0.7 causes the standard deviation of earnings growth to double for both education groups. A large part of

TABLE 4—COMPARATIVE STATICS: VARYING σ_ζ

σ_ζ	π	$\Delta \ln y$	σ_y	Mean duration	Mean $\Delta \ln c_t$		Median $(\Delta A/y)$		
				47–52	25–44	45–62	25–35	36–50	51–62
High education									
0.053	0.125	0.021	0.299	2.0	0.033	0.005	0.026	0.16	0.18
0.095	0.033	0.006	0.324	4.7	0.029	0.012	0.11	0.24	0.10
0.106	**0.0**	**0.0**	**0.332**	**6.0**	**0.029**	**0.013**	**0.14**	**0.25**	**0.076**
0.159	−0.188	−0.039	0.367	13.1	0.030	0.015	0.27	0.24	−0.068
Low education									
0.053	0.085	0.050	0.400	2.9	0.018	0.005	0.014	0.19	0.085
0.095	**0.0**	**0.0**	**0.420**	**8.1**	**0.017**	**0.010**	**0.10**	**0.17**	**−0.010**
0.106	−0.027	−0.012	0.425	9.4	0.017	0.011	0.14	0.17	−0.036
0.159	−0.161	−0.056	0.449	14.2	0.019	0.014	0.24	0.16	−0.16

Notes: σ_y is the standard deviation of annual earnings growth. For the columns concerning the amount of assets, the denominator is average realized earnings (net of the fixed cost of work) in the education-specific baseline. Consumption growth is annualized consumption growth. Unemployment duration is measured in quarters. The baseline case is in bold.

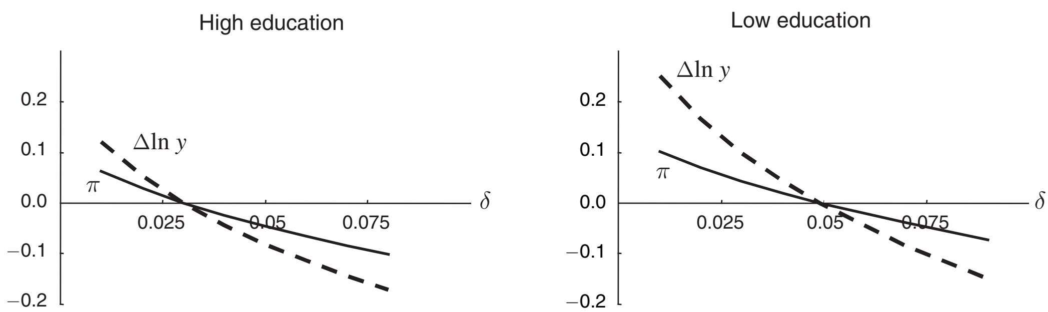

FIGURE 7. WELFARE COSTS AND OUTPUT EFFECTS OF VARYING JOB DESTRUCTION

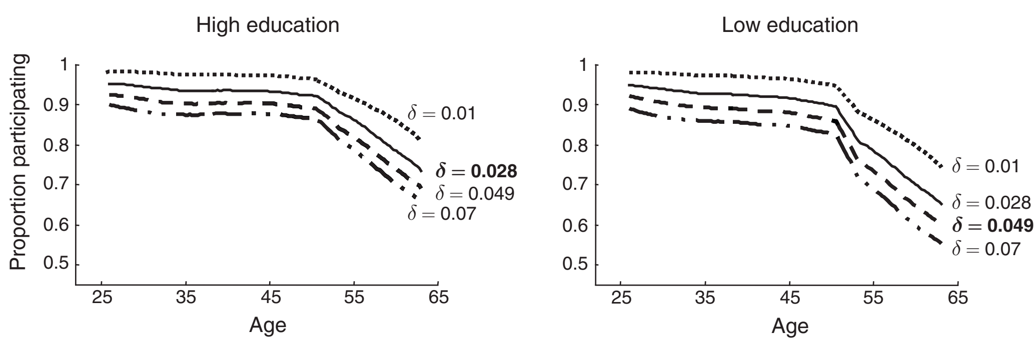

FIGURE 8. EFFECT ON EMPLOYMENT OF VARYING JOB DESTRUCTION

this change in variability of earnings occurs because of the periods of nonemployment that job destruction induces.

Durations of unemployment are shorter when δ is higher because of a composition effect: more of the unemployed are out of work because of job destruction than because of low productivity,

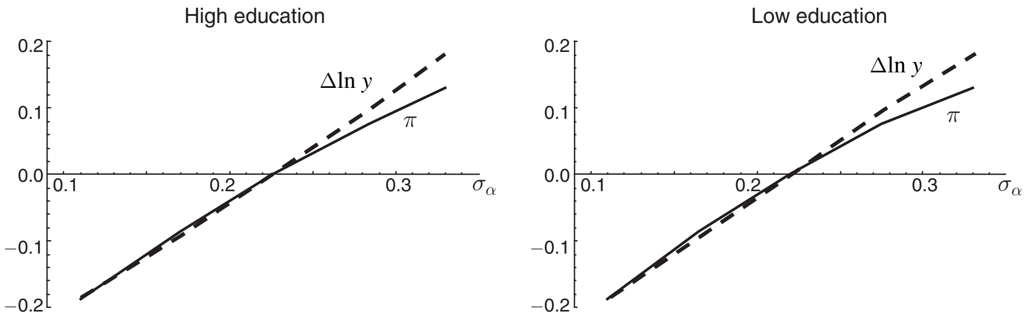

Figure 9. Welfare Costs and Output Effects of Varying Firm Heterogeneity

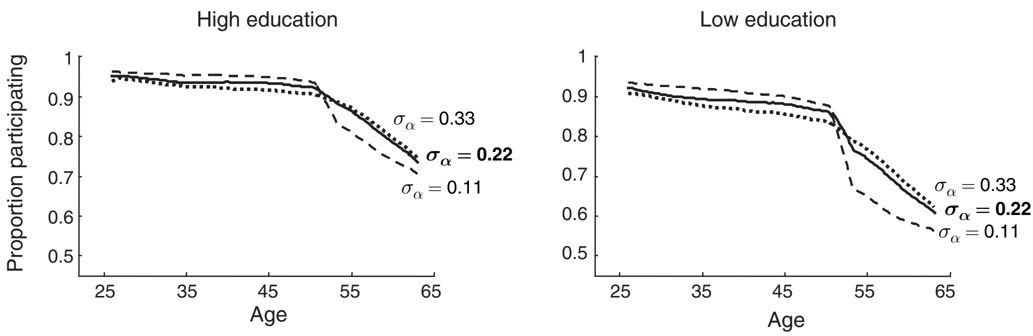

Figure 10. Effect on Employment of Varying Firm Heterogeneity

and so are more likely to receive job offers above their reservation wage. The rate of wealth accumulation decreases with a higher value of δ because the increase in time unemployed reduces opportunities for accumulation.

Firm Heterogeneity.—Figure 9 shows the impact on welfare and output of varying firm heterogeneity, σ_a. Increasing firm heterogeneity implies a greater variety of firms in terms of their productivity. However, because of on-the-job search the best firms tend to be overrepresented in terms of accepted offers, which pushes output up, as clearly seen in the figure. This effect of selection into the best firms leads to greater employment among older individuals when heterogeneity is increased, as shown in Figure 10. Increased heterogeneity therefore pushes welfare up, but not as much as output: increasing heterogeneity implies an increase in the cost of job loss because workers are in danger of losing a more coveted job. Interestingly the effect is not symmetric around our baseline estimates: decreasing firm heterogeneity decreases welfare as much as it does output.

More details of the effects of varying σ_a on behavior are provided in Table 12 of the online Appendix C. In summary here, for those aged 25–35, greater firm heterogeneity leads to faster wealth accumulation for the high-education group, but to slower wealth accumulation for the low-education group. This reflects the offsetting incentives caused on the one hand by greater risk inducing faster accumulation, while on the other hand, the greater expected future income induces slower accumulation.

Table 5—Welfare Loss Comparing Productivity Risk and Job Destruction

Scenario	ΔParameter	Willingness to pay percent ($\pi \times 100$)	$\Delta \ln y$ ($\times$ 100)
High education			
Job destruction, δ	$0.028 \rightarrow 0.026$	0.49	0.95 percent
Productivity shocks, σ_ζ	$0.106 \rightarrow 0.094$	3.48	0.66 percent
Low education			
Job destruction, δ	$0.049 \rightarrow 0.045$	0.74	1.67 percent
Productivity shocks, σ_ζ	$0.095 \rightarrow 0.077$	4.05	2.73 percent

Notes: The table shows the implications of a reduction in the job destruction rate and in the standard deviation of the innovations to wages that each, respectively, lead to a decrease in the variance of annual income growth by 5 percent. The standard deviation of income growth decreases from 0.332 to 0.324 for the low educated and from 0.420 to 0.409 for the high educated.

Offer Arrival Rates.—The overall impact of varying the arrival rate of job offers when unemployed is shown in Table 13 of the online Appendix C and summarized here. The faster arrival rate of offers reduces involuntary unemployment but may increase voluntary unemployment, as the opportunity cost of waiting for a better offer declines (as discussed in Krusell et al. 2008). Which of these effects dominates in the simulations depends on age: for those under 50, employment falls as λ^n increases from 0.66 to 0.96, whereas for those over 50, employment rises. For the low educated, the fall among the young is less, and the rise among the old is greater, than for the high educated. The net changes are, however, very small. Further, average unemployment durations decrease by about one month. Overall, these changes in employment, alongside the improved matching, lead to output increasing for the low educated by two percent, and for the high educated by one percent.

These effects translate into welfare gains of 1.6 percent and 1.2 percent, respectively. Compared to the output change, this suggests the high educated value the increased arrival rate more highly. This is because the opportunity cost of being unemployed is greater for the high educated: the high educated receive higher wage offers and are not as well insured as the low educated by the Unemployment Insurance and Food Stamps programs. For both groups, rates of wealth accumulation are hardly affected by the changing arrival rate.

C. *Comparing Wage Risk and Job Destruction*

In this section we carry out the following simple experiment as one way of comparing the relative importance of wage risk with the risk of job destruction.[47] For each education group, we compute the unconditional variance of annual income growth ($\Delta \ln y_{it}$) as implied by our model (and which matches the data closely). We then consider the welfare effects of decreasing this variance by five percent, first by decreasing the job destruction rate and then by decreasing the variance of the permanent shock to wages. This provides a metric for comparing the two types of risk. The required change in the parameter to achieve this is presented in Table 5 with the other results of this experiment.

For both education groups, the willingness to pay for lowering the variance of annual income growth by five percent via a reduction in the variance of productivity shocks is substantially

[47] We thank Richard Rogerson for this suggestion.

Table 6—Welfare Effects of Government Programs

	High education	Low education
Scenario	Willingness to pay percent ($\pi \times 100$)	Willingness to pay percent ($\pi \times 100$)
Unemployment insurance	0.19	0.24
Food stamps	0.25	0.30
Tax change	0.08	0.15

higher than when this is achieved through a reduction in the rate of job destruction. The output effect of these reductions is different for the two education groups: for the low-education group a reduction in job destruction leads to a higher increase in output than does a reduction in the variance of the productivity shocks. The reverse is true for the higher education group. This, however, does not change the fact that both groups would rather see a reduction in the variance of productivity shocks. Based on this metric productivity risk is more costly than employment risk. Part of the reason for this is that productivity risk tends to increase the variance of the permanent component of earnings, whereas job destruction has less persistent effects on income.

D. *Implications of Government Insurance*

Our framework is well suited for evaluating the welfare effects of the various programs. Such an evaluation requires a life-cycle model where risk plays an important role, and where labor supply is endogenous in order to capture the key source of moral hazard and a further mechanism of self-insurance over and above savings. The Food Stamps program tends to provide partial insurance for income loss whatever the source of the loss, while UI offers compensation when income loss is associated with job destruction. As such each program can be thought of as targeting different risks, although they are unlikely to provide anything close to full insurance. We now turn to a brief examination of the welfare effects of these two social insurance programs.[48]

We consider a small (one percent) increase in the government spending on social insurance and compare the welfare effects of channeling this change, in turn, into UI and into the Food Stamps-type program. This calculation focuses on the insurance benefit of these programs because there is no cross-group redistribution. The results are presented in rows 1 and 2 of Table 6. Row 3 considers the welfare benefit of using the extra spending to reduce the proportional tax rate. For both education groups the most valuable program is the means-tested program because it provides some insurance against large negative (and permanent) shocks. In considering the tax cut, the two groups are willing to pay 0.08 percent and 0.15 percent of consumption, respectively, to see the one percent increase in expenditure going to a tax cut. This implies that both groups prefer the money to be spent on UI or the means-tested program, rather than on a decrease in taxation within their own group.[49]

[48] There are two caveats to these comments: first, these calculations ignore the interactions that may arise between increases in the tax rate needed to fund increased generosity of a program and the take-up of that program: the increased tax rate will make programs more valuable by reducing the benefit of being at work. Second, in practice these programs are funded by taxing the general population and consequently involve a large component of cross-group insurance.

[49] We do not present numbers for increasing the spending on the Disability Insurance program. In our model, spending on the Disability Insurance and Social Security program is valued less than the tax cut. However, our model of DI in effect abstracts from the impact of large or catastrophic health shocks against which insurance is likely to be very valuable and which is provided mainly by DI in reality.

VII. Conclusions

The nature and sources of risk are particularly important in understanding how to design public insurance programs such as unemployment and disability insurance, Food Stamps and other income support programs found across many countries. In this paper we take the first step in understanding and quantifying different sources of risk that we broadly define as productivity and employment risk. In our model productivity risk is identified by permanent shocks to wage rates, while employment risk is generated by job destruction and by the fact that matches are heterogeneous and so the nature of the job obtained has a random component to it. We demonstrate the welfare effects of varying each type of risk and show the output implications of these changes. Varying productivity risk has relatively low impact on output, because low draws are counteracted by high productivity outcomes for other people. However, the welfare effects of changing productivity risk are very high. On the other hand, increasing job destruction rates has a large impact on output through the increased periods of nonemployment, as well as increasing the variance of income. The effect on welfare is relatively low, however, because its impact is transitory. Finally, the large heterogeneity in match quality is highly valued for the possibilities it offers for wage growth over the life cycle.

Our paper is clearly only a step in understanding the role of risk and the way it interacts with welfare programs. One important avenue for further research, taken up by Low and Pistaferri (2009) is that of modeling the nature of different shocks (such as health shocks) using direct information. This will allow for modeling in a more complete setting the participation and entitlement to programs such as Disability Insurance.

We have also highlighted the importance of modeling the wage process and disentangling the impact of exogenous fluctuations from that of fluctuations resulting from responses to shocks, such as moving jobs or quitting work. Indeed we show that our approach leads to a much lower estimate for the variance of the productivity shock than that implied by the usual modeling of the stochastic process for income. The next step in this research agenda is to model explicitly the sources of these shocks, derive the implications for equilibrium pay setting, and link these to the match-specific effect and its stochastic properties. This will allow one to model explicitly how pay would change as risk parameters are modified or in response to welfare programs. Some first steps in this direction are the models of Jeremy Lise, Meghir, and Robin (2009). However, these models still do not allow for risk aversion, which would be a crucial component for applying them in this setting. Finally, allowing for macroeconomic shocks would allow us to revisit their relative importance to idiosyncratic shocks as in Lucas (1987) in a richer setting, and to examine the way that micro and macro shocks interact.

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