Journal of Monetary Economics 76 (2015) 38–54

Contents lists available at ScienceDirect

Journal of Monetary Economics

journal homepage: www.elsevier.com/locate/jme

Inter-industry wage differentials revisited: Wage volatility and the option value of mobility

Seth Neumuller *

Department of Economics, Pendleton East, Wellesley College, 106 Central Street, Wellesley, MA 02481, United States

ARTICLE INFO

Article history:
Received 21 March 2014
Received in revised form
24 July 2015
Accepted 3 August 2015
Available online 12 August 2015

Keywords:
Inter-industry wage differentials
Wage volatility
Option value
Mobility

ABSTRACT

Analysis of data from the PSID reveals that idiosyncratic wage volatility varies inversely with inter-industry wage differentials and is positively correlated with both returns to industry tenure and rates of inter-industry mobility. An incomplete markets life cycle model in which inter-industry mobility decisions and wage differentials are endogenously determined in equilibrium is then developed and shown to be capable of rationalizing these features of the data. In the model, the ability of worker to switch industries generates option value that is large enough to offset the standard risk premium that workers demand for exposure to excess wage volatility.

1. Introduction

It is well known that even after controlling for human capital and demographic factors, industry affiliation has a large and statistically significant impact on an individual's wage.[1] Identifying the underlying source of inter-industry wage differentials, however, has proven elusive. One strand of this literature, including the seminal work of Krueger and Summers (1988), argues in favor of non-competitive theories of wage determination. For example, firms in a given industry may pay high wages in order to minimize turnover costs, encourage worker effort, increase worker loyalty, or attract better workers. Another strand of this literature, including the studies by Rosen (1986) and Gibbons and Katz (1992), contends that wage differentials arise in competitive labor markets as a result of systematic variation in either worker characteristics or job attributes. For example, workers in high wage industries may be more productive along dimensions that are not captured by individual-level data sets. Alternatively, high wages might reflect compensating differentials demanded by workers for exposure to onerous work conditions or excess unemployment risk. The positive and normative implications of non-competitive theories of wage determination, however, are considerably different from those of standard competitive models.[2] Thus, resolving this tension is of primary importance for designing effective labor market policies and evaluating allocative efficiency. This paper explores the empirical and theoretical relationships between the level and variability of wages across industries and finds that exogenous variation in wage uncertainty, coupled with endogenous inter-industry

* Tel.: +1 781 283 2669.
E-mail address: seth.neumuller@wellesley.edu

[1] Dickens and Katz (1987) offer a comprehensive review of the early empirical literature on this subject. Caju et al. (2010) provide an updated literature review with an emphasis on studies of labor markets outside of the United States.

[2] See, for example, Stiglitz (1986) and Bulow and Summers (1986).

http://dx.doi.org/10.1016/j.jmoneco.2015.08.001
0304-3932/

mobility decisions over the life cycle, can account for much of the observed industry wage structure in the context of a perfectly competitive labor market.

The empirical relationship between the level and variability of wages across industries is first explored by constructing estimates of inter-industry wage differentials and wage volatility using data from the *Panel Study of Income Dynamics* (PSID). Inter-industry wage differentials are estimated using a standard cross-section wage equation with controls for human capital and demographic factors. The volatility of industry-specific idiosyncratic wage shocks is then estimated by comparing the observed wage changes of industry-stayers to those predicted by the fitted wage equation. The results of this analysis indicate that the volatility of persistent idiosyncratic wage shocks (1) varies substantially across industries, (2) is inversely related to inter-industry wage differentials, (3) is positively correlated with returns to industry tenure, and (4) is positively correlated with rates of inter-industry mobility. In other words, industries that expose workers to *high* levels of persistent wage volatility pay relatively *low* wages, and exhibit higher than average returns to tenure and turnover rates.

Motivated by these empirical facts, this paper hypothesizes that the ability to switch industries is an important insurance mechanism that increases the relative attractiveness of employment in industries with a high degree of wage uncertainty. If adverse wage shocks drive mobility decisions, then we would expect to observe a positive relationship between the volatility of industry-specific idiosyncratic wage shocks and rates of inter-industry mobility. Moreover, the resulting selection effects would then generate what appears to be excess returns to tenure for those industries with highly volatile wage shock processes.

To evaluate the merits of this hypothesis, a general equilibrium incomplete markets model of sorting across industries over the life cycle is developed. In the model, workers are heterogeneous in labor productivity and there are many spatially segmented competitive labor markets, or islands as in Lucas and Prescott (1974), each representing an industry in which workers can seek employment. Islands vary exogenously in the volatility of the idiosyncratic labor productivity shocks that workers face.[3] At any time, workers can pay a utility cost to learn their productivity on another island and have the option to switch to that island if they so desire. Since workers are risk averse, the inability to perfectly insure against productivity shocks puts upward pressure on wages on those islands with the most volatile shock processes (*risk effect*). But since workers have the option to switch islands in response to an adverse labor productivity shock, islands with highly volatile shock processes offer the potential for rapid wage growth with limited downside risk (*option effect*). The equilibrium industry wage structure, denominated in units of the consumption good per efficiency unit of labor, is determined by the relative strength of these opposing forces.

A fitted version of the model is able to replicate the inverse empirical relationship between the level and volatility of wages for plausible levels of risk aversion and is jointly consistent with the empirically observed relationships between within-industry wage volatility, returns to industry tenure, and patterns of inter-industry mobility over the life cycle. The fitted model thus implies that inter-industry mobility is a quantitatively important insurance channel against wage risk which more than offsets the risk premium workers demand for exposure to excess wage volatility. A counter-factual exercise in which inter-industry mobility is prohibited reveals that workers would be willing to give up 3.3% of their expected lifetime consumption for the option to switch industries in response to an adverse labor productivity shock. Thus, the welfare gains from inter-industry mobility are quite large.

The structural model serves as a guide for interpreting the data. In particular, the model points to three factors that jointly account for the inverse empirical relationship between the level and volatility of wages across industries: (1) compensating differentials that reflect the net trade-off between the risk and option effects, (2) systematic sorting on labor productivity over the life cycle, and (3) selection bias in estimates of within-industry wage volatility. To start, the option effect dominates the risk effect in equilibrium, leading to an inverse relationship between the level and volatility of wages denominated in units of the consumption good per efficiency unit of labor. The equilibrium distribution of labor productivity across islands is determined by endogenous mobility decisions over the life cycle and is unobservable to the econometrician. As a result, industry tenure will be positively correlated with the error term in a standard cross section wage equation, leading to biased estimates of industry-level fixed-effects which contribute to the observed inverse empirical relationship. Finally, selection effects bias estimates of within-industry wage volatility in a reinforcing manner. The fitted model is used to quantify the relative importance of each factor. Indeed, the fitted model helps us disentangle what we observe in the data, which is particularly useful in this situation given the important role of selection on unobservables in generating the observed industry wage structure. The results of this exercise suggest that each factor contributes in a significant way to the observed relationship between the level and volatility of wages across industries.

Mine is not the first paper to investigate the relationship between risk and return across industries. Abowd and Ashenfelter (1981), for example, find a positive relationship between inter-industry wage differentials and unemployment risk in PSID data between 1967 and 1975, while Murphy and Topel (1987) analyze two-year panels of individuals in the Current Population Survey (CPS) between 1977 and 1984 and document wide differences in the volatility of hours worked and annual earnings across industries. In a recent working paper, Cubas and Silos (2012) identify a positive correlation between the variability and level of labor income across industries using monthly data from the Survey of Income and

[3] Explaining why wage uncertainty varies across industries is beyond the scope of this paper. However, Lagakos and Ordonez (2011) demonstrate that differences in equilibrium risk sharing arrangements between firms and workers may contribute to observed variations in industry-level wage risk.

Program Participants (SIPP) aggregated at a quarterly frequency.[4] The authors then construct a general equilibrium model of sorting in the labor market wherein agents are ex ante heterogeneous in terms of their comparative advantage to work in each sector. While Cubas and Silos (2012) explore the effects of sorting across industries at entry into the labor market, this paper highlights the importance of sorting across industries over the life cycle. Also, in contrast to much of this literature, the focus here is on the relationship between the variability and level of *wages* given *flexible* labor supply, rather than the variability and level of *labor income* given *fixed* labor supply.[5] Allowing for endogenous labor supply decisions is important because the ability to adjust hours can potentially mitigate the risk of labor productivity shocks.[6] Moreover, when measured on a biennial basis, wages are nearly twice as volatile as hours worked.[7]

Finally, the idea that, conditional on mean return, workers may prefer jobs with greater earnings uncertainty is not new. Vereshchagina and Hopenhayn (2009), for example, show that the ability of an entrepreneur to close down their business and enter the workforce explains why entrepreneurs are willing to take on a disproportionate amount of earnings risk in exchange for a relatively low expected return. In a related study, Kaplan (2012) argues that the ability to move into and out of the parental home allows young workers to pursue riskier jobs which offer faster expected wage growth. This idea is also central to the job shopping theories of Johnson (1978) and Viscusi (1980) and the job matching theories of Jovanovic (1979), Miller (1984), and Harris and Weiss (1984). This paper contributes to the literature by developing a quantitative theory of sorting on the labor market and demonstrating that the option to switch industries plays a key role in explaining why young workers disproportionately expose themselves to excess wage risk in exchange for a low expected wage.

The remainder of this paper proceeds as follows. Section 2 outlines the empirical analysis and main findings. Section 3 describes the theoretical framework. Section 4 reports the results from a fitted version of the theoretical model. Finally, Section 5 concludes.

2. Empirical facts

This section documents empirical relationships between the industry wage structure, returns to industry tenure, idiosyncratic within-industry wage volatility, and inter-industry mobility patterns using data from the PSID.

2.1. The panel study of income dynamics

The PSID is a comprehensive longitudinal household survey that began in 1968 and includes questions pertaining to employment, income, wealth, education, and health, as well as numerous other topics. Information on individuals in the original, nationally representative sample and their descendants was collected annually through 1997 and biennially thereafter. This paper employs data for working age males from the merged family- and individual-level files on age, years of education, labor force participation, self-employment status, hours worked, union membership status, job tenure, and labor income, the latter of which is defined to be the sum of wages, bonuses, commissions, and overtime pay. The PSID also reports each individual's occupation and industry affiliation at the three-digit level.[8] Due to sample size restrictions and reporting practices, the analysis presented here is conducted using 18 industry classifications based loosely on the 1970 Census Two-digit Industry Codes.[9]

2.2. A reduced form model of wage dynamics

The following model of wage dynamics allows for a straight-forward estimation of inter-industry wage differentials as in Krueger and Summers (1988), returns to industry tenure, and the volatility of persistent and transitory shocks to wages following Meghir and Pistaferri (2004), among others. In particular, the log of individual i's real wage evolves according to

$$\ln w_{i,t} = \eta_{j,t} + \tau_{i,j}\Psi_j + x_{i,j,t}\psi + f(a_{i,t}) + z_{i,j,t} + e^b_{i,j,t} \tag{1}$$

[4] Estimates of income volatility obtained using data from the SIPP are sensitive to the chosen aggregation time frame due to seam bias (see Moore, 2008). Lengthening the aggregation time frame reduces the effects of seam bias at the cost of fewer observations of labor income per individual. When the monthly observations employed by Cubas and Silos (2012) are aggregated at an annual frequency, the relationship between the variability and the level of labor income across industries is no longer statistically different from zero. Importantly, the main theoretical results documented here are robust to the use of annual wage volatility estimates from the SIPP. Details of this analysis are included in the supplementary material.

[5] In the supplementary material, the empirical facts documented here using wages are shown to be qualitatively similar to the results obtained when using labor income.

[6] See Heathcote et al. (2008). Consumers may choose to use hours worked to mitigate fluctuations in labor income by increasing (decreasing) labor supply when wages fall (rise). Alternatively, consumers may elect to work more hours in periods when their wages are high, thereby increasing average earnings per hour.

[7] See the supplementary material for details.

[8] Between 1968 and 1980, the PSID recorded occupations and industries using various combinations of one- and two-digit codes. The 1968–1980 Retrospective Occupation-Industry Files provide 1970 Census Three-digit Codes for the occupation and industry of each individual's main job for all sample years prior to 1981 based on a recoding of handwritten job descriptions.

[9] There are 30 industry designations in the 1970 Census Two-digit Industry Codes. Industries are aggregated until a sufficient number of industry-year observations within each resulting industry aggregate is obtained to permit statistical inference. Details of sample selection and industry aggregation procedures are included in the supplementary material.

where $\eta_{j,t}$ is an *(industry)* x *(year)* effect specific to industry j in year t, $\tau_{i,j}$ is years of tenure for individual i in industry j, Ψ_j is returns to tenure in industry j, $x_{i,j,t}$ is a vector of controls (years of education, union membership status, occupation, firm tenure, and occupational tenure), $a_{i,t}$ is the age of individual i, and $f(a_{i,t}) = \theta_1 a_{i,t} + \theta_2 a_{i,t}^2 (10)^{-2}$. Finally, $e^b_{i,j,t} \sim N(0, \sigma^b_{e,j})$ is an i.i.d. biennial transitory wage shock and $z_{i,j,t}$ is the permanent component of the log of the real wage for individual i which evolves according to

$$z_{i,j,t} = z_{i,j,t-2} + \zeta^b_{i,j,t}, \tag{2}$$

where $\zeta^b_{i,j,t} \sim N(0, \sigma^b_{\zeta,j})$ is an i.i.d. biennial permanent wage shock.[10] [11]

The fixed-effect of employment in industry j, ω_j, is then defined as the weighted average of $\eta_{j,t}$ for industry j across all sample years, or

$$\omega_j \equiv \frac{1}{n_j} \sum_t \xi_{j,t} \eta_{j,t} \tag{3}$$

where $\xi_{j,t}$ is the number of individuals employed in industry j during sample year t and $n_j \equiv \sum_t \xi_{j,t}$ is the total number of individual-year observations for industry j. Lastly, the wage differential for industry j, Ω_j, is defined as the difference between ω_j and a weighted average of ω_j across all industries, or

$$\Omega_j \equiv \omega_j - \frac{1}{N} \sum_j n_j \omega_j \tag{4}$$

where $N \equiv \sum_j n_j$ is the total number of individual-year observations in my dataset.

Taking first differences of Eq. (1) for individuals who do not switch industries between dates t and $t-2$, after substituting in for $z_{i,j,t}$ using Eq. (2), leads to the following wage growth equation:

$$\Delta \ln w_{i,t} = \Delta\left(\hat{\eta}_{j,t} + 2\hat{\Psi}_j + x_{i,j,t}\hat{\psi} + \hat{f}(a_{i,t})\right) + \left(\zeta^b_{i,j,t} + \Delta e^b_{i,j,t}\right). \tag{5}$$

The volatility of within-industry permanent and transitory shocks to wages can then be estimated as follows. The left-hand side of Eq. (5) is observed wage growth, while the first term on the right-hand side is that which is predicted by the reduced form model of wage dynamics based solely on observable factors. The second term on the right-hand side of Eq. (5) is then the unpredictable component of wage growth, or the cumulative wage shock:

$$g_{i,j,t} \equiv \zeta^b_{i,j,t} + (e^b_{i,j,t} - e^b_{i,j,t-2}). \tag{6}$$

Computing the variance and first-order autocovariance of $g_{i,j,t}$ leads to a system of two equations which can be solved jointly for the volatility of biennial permanent and transitory wage shocks for industry j:

$$\sigma^b_{\zeta,j} = \sqrt{\mathbb{E}[g^2_{i,j,t}] + 2\mathbb{E}[g_{i,j,t} g_{i,j,t-2}]} \tag{7}$$

$$\sigma^b_{e,j} = \sqrt{-\mathbb{E}[g_{i,j,t} g_{i,j,t-2}]}. \tag{8}$$

2.3. Estimation results

Column (1) of Table 1 reports estimates of the inter-industry wage differential, Ω_j, for each industry j relative to public administration, the omitted industry in the OLS regression of Eq. (1). The effect of industry affiliation on wages varies substantially across industries. The weighted standard deviation of $\hat{\Omega}_j$ is 0.078 log points, and a typical worker employed in the machinery industry, for example, earns a wage that is, on average, 26.8% higher than that of an observationally equivalent worker employed in the retail trade industry (i.e. after controlling for human capital and demographic factors).[12]

Estimates of the return to industry tenure, $\hat{\Psi}_j$, for each industry j are reported in Column (2) of Table 1. On average, each additional year of industry experience leads to a 0.0065 log point increase in an individual's wage. Like the effects of industry affiliation, however, returns to tenure also vary substantially across industries. In particular, the weighted standard deviation of Ψ_j is 0.0052 log points, and the difference between the minimum (other manufacturing) and maximum (finance, insurance, and real estate) is 0.0315 log points. Over the course of a typical working career, the compounded effect of these differences is substantial.

[10] The PSID transitioned from an annual to a biennial survey after 1997. To maintain consistency throughout the sample, a two-year panel structure is employed as in Dynan et al. (2012).

[11] Labor productivity shocks are intended to capture uninsurable idiosyncratic risk. Examples of permanent shocks include persistent changes in health status, demographic shocks, promotions, or even demotions. Temporary changes in health status and bonuses are examples of transitory shocks.

[12] The estimates reported in Column (1) of Table 1 are broadly consistent with the corresponding estimates reported by Krueger and Summers (1988) who use data from the CPS.

Table 1
Empirical results.

Industry	(1) $\hat{\Omega}_j$	(2) $\hat{\Psi}_j$	(3) $\hat{\sigma}^b_{\zeta,j}$	(4) $\hat{\sigma}^b_{e,j}$	(5) m_j
Chemicals, refining, rubber, and plastics	0.0796***	0.0087***	0.146	0.135	0.172
	(0.0168)	(0.00149)	(0.0165)	(0.0071)	
Communications and utilities	0.0943***	0.0047***	0.134	0.114	0.082
	(0.0155)	(0.00113)	(0.0153)	(0.0057)	
Construction	0.0391***	0.0065***	0.166	0.152	0.184
	(0.0141)	(0.00116)	(0.0118)	(0.0054)	
Education	−0.0960***	0.0055***	0.139	0.157	0.074
	(0.0175)	(0.00149)	(0.0137)	(0.0050)	
Finance, insurance, and real estate	−0.0241	0.0196***	0.186	0.153	0.132
	(0.0178)	(0.00176)	(0.0152)	(0.0076)	
Food and kindred products	−0.0223	0.0109***	0.138	0.161	0.180
	(0.0191)	(0.00219)	(0.0286)	(0.0096)	
Health services	−0.0829***	0.0096***	0.199	0.141	0.121
	(0.0197)	(0.00191)	(0.0164)	(0.0094)	
Machinery, including electrical	0.104***	0.0038***	0.129	0.126	0.170
	(0.0139)	(0.00116)	(0.0114)	(0.0048)	
Metals	0.0853***	0.0047***	0.110	0.156	0.206
	(0.0158)	(0.00145)	(0.0281)	(0.0077)	
Motor vehicles and transport equipment	0.0564***	0.0046***	0.146	0.142	0.223
	(0.0154)	(0.00148)	(0.0155)	(0.0064)	
Natural resource extraction	−0.0112	0.0029	0.176	0.153	0.216
	(0.0206)	(0.00242)	(0.0195)	(0.0093)	
Other manufacturing	0.0366**	−0.0119***	0.117	0.165	0.231
	(0.0170)	(0.00204)	(0.0295)	(0.0079)	
Other services	−0.0401***	0.0114***	0.167	0.165	0.255
	(0.0140)	(0.00147)	(0.0139)	(0.0060)	
Professional and related services	0.0219	0.0016	0.162	0.145	0.270
	(0.0198)	(0.00272)	(0.0212)	(0.0096)	
Public administration	0.0000	0.0033**	0.147	0.155	0.117
	n/a	(0.00132)	(0.0120)	(0.0047)	
Retail trade	−0.164***	0.0044***	0.152	0.162	0.199
	(0.0136)	(0.00114)	(0.0128)	(0.0050)	
Transportation	0.0304**	0.0111***	0.137	0.168	0.143
	(0.0153)	(0.00137)	(0.0167)	(0.0055)	
Wholesale trade	−0.00853	0.0109***	0.187	0.138	0.301
	(0.0164)	(0.00241)	(0.0147)	(0.0082)	
Employment weighted average	0.000	0.0065	0.153	0.152	0.181
Employment weighted standard deviation	0.078	0.0052	0.021	0.011	0.059

Standard errors in parentheses. $\hat{\Omega}_j$ is the estimated fixed-effect of industry affiliation (inter-industry wage differential), while $\hat{\Psi}_j$ represents the estimated impact of an additional year of industry tenure. $\hat{\sigma}^b_{\zeta,j}$ and $\hat{\sigma}^b_{e,j}$ are the estimated volatility of biennial permanent and transitory wage shocks, respectively. The biennial inter-industry mobility rate, or m_j, is the average fraction of workers leaving industry j for employment in industry $k \neq j$ within any given two year period.

** $p<0.05$.

*** $p<0.01$.

Workers in the PSID switch industries often. Let $m^a_{j,t}$ represent the fraction of workers age a employed in industry j in year t who are employed in another industry $k \neq j$ in year $t+2$. The employment weighted average value of $m^a_{j,t}$ across all ages, industries, and sample years is 0.181, which implies that nearly 1 in 5 workers change industries every two years.[13] Fig. 1 depicts the employment weighted average value of $m^a_{j,t}$ across all industries and sample years as a function of age (m^a). Consistent with Kambourov and Manovskii (2008), mobility rates decrease with labor market experience. Column (5) of Table 1 reports the employment weighted average value of $m^a_{j,t}$ across all ages and sample years by industry (m_j). Like wage differentials and returns to tenure, mobility rates vary widely across industries. For example, the biennial inter-industry mobility rate for the wholesale trade industry is more than three times greater than that for the education sector.

Finally, Eq. (6) is used to compute $g_{i,j,t}$ for industry stayers, and then the sample analogues of Eqs. (7) and (8) are used to estimate the volatility of biennial persistent and transitory shocks to wages for each industry j. The resulting estimates are reported in Columns (3) and (4), respectively, of Table 1. The employment weighted average of $\hat{\sigma}^b_{\zeta,j}$ is 0.153 and the standard deviation is 0.021. The metals industry, for example, has the lowest persistent shock volatility of 0.110, which is nearly 50

[13] In order to identify genuine industry switches in the PSID data, only those changes in industry affiliation that are accompanied by a concurrent change of employer are counted. This procedure, when combined with the use of the 1968–1980 Retrospective Occupation-Industry Files, is shown by Kambourov and Manovskii (2013) to greatly reduce the impact of industry coding errors.

Fig. 1. The fraction of workers switching industries of employment during a two year period by age, m^a. The solid line is computed using data from the PSID. The dashed line is computed using data generated by the calibrated life cycle model.

percent less than that for the health services industry. Thus, the volatility of biennial permanent shocks also varies substantially across industries. There is far less variation, however, in the volatility of biennial transitory shocks for which the employment weighted average and standard deviation are 0.152 and 0.011, respectively.[14]

It is important to point out that the volatilities reported in Columns (3) and (4) of Table 1 are estimated using wage changes for industry stayers only since the within-industry wage changes of workers who decide to switch industries are unobservable. If inter-industry mobility is an endogenous response to adverse permanent labor productivity shocks, then individuals who switch industries are more likely to have drawn a low realization of $\zeta^b_{i,j,t}$. As a result, the biennial persistent wage shock volatilities reported in Column (3) of Table 1 are likely biased down relative to the truth.

Selection bias is addressed using the theoretical model developed in the following section by explicitly allowing for endogenous inter-industry mobility decisions and using indirect inference in the spirit of Smith (1993) and Gourieroux et al. (1993) to obtain unbiased estimates of the true industry-specific *annual* shock volatilities $\sigma_{\zeta,j}$ and $\sigma_{e,j}$. In particular, annual shock volatilities $\sigma_{\zeta,j}$ and $\sigma_{e,j}$ are estimated such that the corresponding model-implied biennial shock volatilities $\sigma^b_{\zeta,j}$ and $\sigma^b_{e,j}$ obtained using Eqs. (7) and (8) match their empirical counterparts.[15] The difference between the resulting selection corrected annual shock volatilities $\sigma_{\zeta,j}$ and $\sigma_{e,j}$, expressed on a biennial basis (multiplied by $\sqrt{2}$), and the uncorrected biennial shock volatilities $\sigma^b_{\zeta,j}$ and $\sigma^b_{e,j}$ reported in Columns (3) and (4) of Table 1 then offers an estimate of the magnitude of this selection bias.

I now briefly preview the results of this analysis. Consistent with the idea that mobility decisions are an endogenous response to adverse permanent labor productivity shocks, selection biases down empirical estimates of the volatility of permanent wage shocks. Interestingly, selection effects upward bias the measured volatility of transitory wage shocks. This is not a priori obvious, but – unlike a notional upward bias in the permanent shock volatility – it is perfectly plausible. For example, suppose that an individual receives repeated adverse permanent labor income shocks (i.e. $\zeta^b_{i,j,t-2} < 0$ and $\zeta^b_{i,j,t} < 0$), and the second of these causes the individual to change industries. Then selection-corrected estimates of $\mathbb{E}[g_{i,j,t}g_{i,j,t-2}]$ (which take into account repeated negative permanent shocks) will be less negative than their uncorrected counterparts. From Eq. (8), we can see that this would lead to selection-corrected estimates of $\sigma^b_{e,j}$ that are smaller than their uncorrected counterparts. In this case, selection effects bias up estimates of the volatility of transitory wage shocks relative to the truth.

2.4. Wage differentials, return to tenure, mobility and volatility

An estimate of the empirical trade-off between risk and return across industries is obtained by regressing inter-industry wage differentials ($\hat{\Omega}_j$) on measures of permanent and transitory idiosyncratic within-industry wage risk ($\hat{\sigma}^b_{\zeta,j}$ and $\hat{\sigma}^b_{e,j}$). The results of this procedure are reported in Column (1) of Table 2. If wage differentials represent compensation for exposure to wage uncertainty, then we would expect the coefficients of $\hat{\sigma}^b_{\zeta,j}$ and $\hat{\sigma}^b_{e,j}$ to be *positive*. The results of this analysis suggest that

[14] Estimates of $\sigma^b_{e,j}$ also reflect measurement error in either the reporting or recording of labor income and hours worked. Carroll and Samwick (1997), however, show that up to MA(2) measurement error will not affect estimates of $\sigma^b_{\zeta,j}$ using the approach employed here.

Overall, the results presented in Columns (3) and (4) of Table 1 are broadly consistent with the corresponding annualized estimates reported by Carroll and Samwick (1997). While these authors also use data from the PSID in their analysis, this paper employs data from a larger number of surveys which allows for more disaggregated and precise estimates of wage volatility at the industry level.

[15] As a robustness check, a Heckman selection model is also used to obtain selection corrected estimates of the *biennial* shock volatilities $\sigma^b_{\zeta,j}$ and $\sigma^b_{e,j}$. The results of this analysis are consistent with the results obtained using indirect inference. Details of this analysis are included in the supplementary material.

Table 2
Wage uncertainty, wage differentials, returns to tenure, and mobility.

Variable	(1) $\hat{\Omega}_j$	(2) $\hat{\Psi}_j$	(3) m_j
$\hat{\sigma}^b_{\zeta,j}$	−1.334***	0.1029***	0.566*
	(0.391)	(0.0332)	(0.322)
$\hat{\sigma}^b_{e,j}$	−3.499***	0.0658	0.183
	(0.612)	(0.0519)	(0.501)
Constant	0.731***	−0.0193**	0.066
	(0.094)	(0.0086)	(0.069)
R^2	0.433	0.291	0.071

Bootstrap standard errors in parentheses. Results of regressing estimated inter-industry wage differentials $\hat{\Omega}_j$, returns to industry tenure $\hat{\Psi}_j$, and inter-industry mobility rates m_j on the estimated volatility of biennial permanent and transitory wage shocks $\hat{\sigma}^b_{\zeta,j}$ and $\hat{\sigma}^b_{e,j}$, respectively, and a constant.
* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

precisely the opposite is true – the coefficients of both $\hat{\sigma}^b_{\zeta,j}$ and $\hat{\sigma}^b_{e,j}$ are *negative* and significantly different from zero ($p < 0.01$), meaning that individuals who expose themselves to higher (lower) levels of wage uncertainty do so in exchange for a lower (higher) expected wage. Moreover, the inverse relationship between risk and return is quite strong, as variations in $\hat{\sigma}^b_{\zeta,j}$ and $\hat{\sigma}^b_{e,j}$ across industries explain 43.3 percent of the industry wage structure.[16]

Can variations in wage uncertainty account for differences in estimated returns to tenure across industries? To answer this question, $\hat{\Psi}_j$ is regressed on $\hat{\sigma}^b_{\zeta,j}$, $\hat{\sigma}^b_{e,j}$, and a constant. Results of this OLS regression are reported in Column (2) of Table 2. The coefficient on $\hat{\sigma}^b_{\zeta,j}$ is positive and significant ($p < 0.01$), while the coefficient on $\hat{\sigma}^b_{e,j}$ is not significantly different from zero. Thus, individuals who expose themselves to high levels of persistent wage uncertainty do so in exchange for a lower expected wage and higher returns to tenure. This finding could potentially be explained by selection effects – individuals who experience positive persistent labor productivity shocks are more likely to remain in their current industry of employment. Differences in the volatility of persistent shocks to wages across industries then lead to variations in estimates of returns to tenure. If this hypothesis is correct, then estimates of returns to industry tenure should be increasing in the volatility of persistent shocks to wages as documented here.

To what extent can differences in mobility rates across industries be explained by variations in the volatility of persistent shocks to wages? Column (3) of Table 2 reports the results of an OLS regression of the employment weighted average value of $m^a_{j,t}$ across all ages and sample years by industry (m_j) on $\hat{\sigma}^b_{\zeta,j}$, $\hat{\sigma}^b_{e,j}$, and a constant. The coefficients on both regressors are positive, indicating that industries which expose workers to higher levels of wage uncertainty, particularly persistent wage uncertainty, are more likely to experience higher turnover rates.

Finally, the empirical relationship between the within-industry volatility of persistent shocks to wages and patterns of mobility over the life cycle is examined. Given the limited number of individual-year observations in the baseline sample, the 18 industries are further aggregated into 4 equally weighted groups based on the estimates of $\hat{\sigma}^b_{\zeta,j}$ reported in Column (3) of Table 1. This procedure results in the following groups, ordered from least to greatest in terms of average persistent wage uncertainty: (1) communications and utilities; machinery; metals; other manufacturing; transportation, (2) chemicals, refining, rubber, and plastics; education; food and kindred products; motor vehicle and transport equipment; public administration, (3) construction; professional and related services; retail trade, and (4) finance, insurance, and real estate; health services; natural resource extraction; other services; wholesale trade. Table 3 reports summary statistics for each group. Group 1, which is made up of industries with the lowest levels of persistent wage uncertainty, has the lowest average return to industry tenure and mobility rate, but the highest average wage differential. Group 4, on the other hand, which is made up of industries with the highest levels of persistent wage uncertainty, has the highest average return to industry tenure and mobility rate, but the second lowest average wage differential. Fig. 2 (a) depicts the fraction of workers employed

[16] The results of the cross-industry regression presented in Column (1) of Table 2 do not include controls for other industry-level characteristics which might be correlated with both wage volatility and wage differentials. For example, one might expect industries with high rates of unionization to be characterized by high wages and low volatility. In order to rule out this and many other potential alternative empirical interpretations of the data, the analysis performed here is repeated using the following selected samples: non-union (those not affiliated with a labor union), unskilled (those with at most a high school diploma), skilled (those with at least a 4 year college degree), 1967–1984 (the first half of my sample period), 1985–2008 (the second half of my sample period), and with self-employed (including those who report being self employed). Results are summarized in the supplementary material. While there is minor variation in the regression coefficients across subsamples, the coefficient on $\hat{\sigma}^b_{\zeta,j}$ is always negative. For the subsample of non-union workers, for example, the coefficient on $\hat{\sigma}^b_{\zeta,j}$ is -1.216 ($p < 0.05$) which suggests that differences in rates of unionization across industries may be a contributing factor, but cannot fully account for the negative relationship between risk and return documented here.

Table 3
Industry group summary statistics.

Variable	Group 1	Group 2	Group 3	Group 4
Fraction of total observations	0.246	0.256	0.240	0.258
Fraction of 19-year-olds	0.194	0.219	0.370	0.220
Average wage differential	0.076	−0.001	−0.052	−0.029
Average volatility of $\zeta_{i,t}$ (*biennial*)	0.128	0.144	0.159	0.180
Average volatility of $e_{i,t}$ (*biennial*)	0.150	0.151	0.155	0.152
Average returns to tenure (*annual*)	0.0039	0.0055	0.0048	0.0114
Average mobility rate (*biennial*)	0.163	0.139	0.203	0.219

Summary statistics of data from the PSID stratified by industry group. Industry groups are formed by ranking industries from low to high in terms of the estimated volatility of persistent idiosyncratic wage shocks and then partitioning them into four approximately equally weighted bins (in terms of the total number of industry–year observations). The industries represented by each group are (1) communications and utilities; machinery; metals; other manufacturing; transportation, (2) chemicals, refining, rubber, and plastics; education; food and kindred products; motor vehicle and transport equipment; public administration, (3) construction; professional and related services; retail trade, and (4) finance, insurance, and real estate; health services; natural resource extraction; other services; wholesale trade.

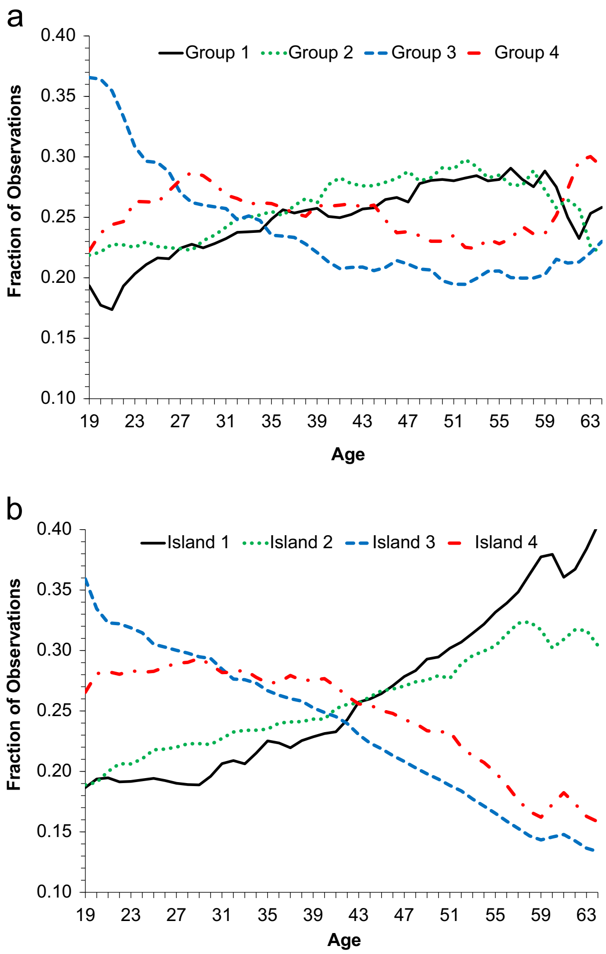

Fig. 2. Fraction of workers employed in each industry group in the PSID or island in the calibrated life cycle model by age. The industries represented by each group/island are: (1) communications and utilities; machinery; metals; other manufacturing; transportation, (2) chemicals, refining, rubber, and plastics; education; food and kindred products; motor vehicle and transport equipment; public administration, (3) construction; professional and related services; retail trade, and (4) finance, insurance, and real estate; health services; natural resource extraction; other services; wholesale trade. (a) Data (b) Model.

in each group as a function of age. Young workers are disproportionately employed in industries with high levels of persistent wage uncertainty (Groups 3 and 4), while older workers tend to be employed in industries with low levels of persistent wage uncertainty (Groups 1 and 2). Panel (a) of Table 4 reports the empirical transition matrix between groups.

Table 4
Industry group transition matrix.

Panel (a): Using data from the PSID				
	Date t			
Date $t-2$	Group 1	Group 2	Group 3	Group 4
Group 1	0.883	0.037	0.035	0.045
Group 2	0.036	0.884	0.039	0.041
Group 3	0.039	0.041	0.845	0.075
Group 4	0.045	0.046	0.064	0.846
Panel (b): Using data generated by the model				
	Date t			
Date $t-2$	Group 1	Group 2	Group 3	Group 4
Group 1	0.831	0.095	0.026	0.048
Group 2	0.096	0.809	0.039	0.055
Group 3	0.043	0.049	0.818	0.090
Group 4	0.055	0.059	0.081	0.805

The industries represented by each group are (1) communications and utilities; machinery; metals; other manufacturing; transportation, (2) chemicals, refining, rubber, and plastics; education; food and kindred products; motor vehicle and transport equipment; public administration, (3) construction; professional and related services; retail trade, and (4) finance, insurance, and real estate; health services; natural resource extraction; other services; wholesale trade.

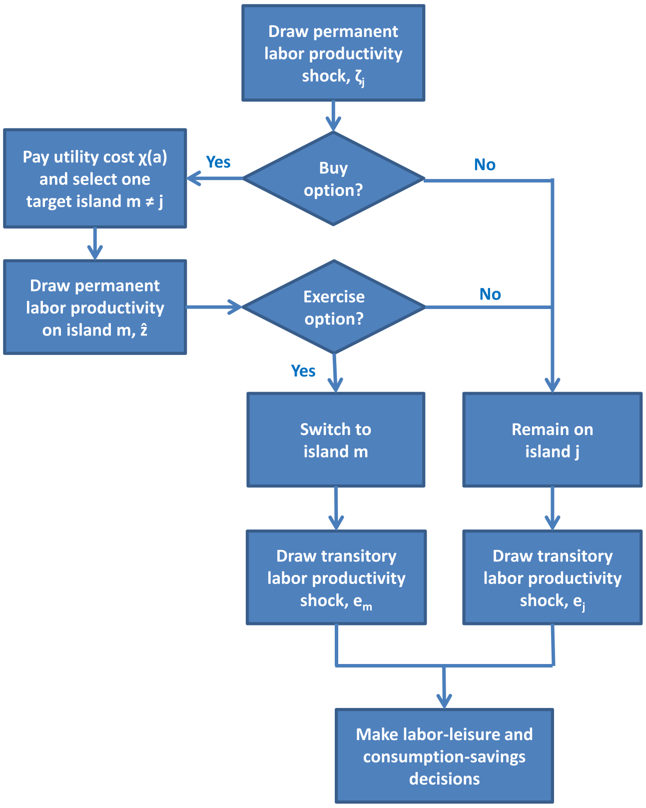

Fig. 3. The timing of exogenous shocks and decisions made by workers within a period of the theoretical life cycle model.

The probability of switching groups is weakly increasing in the average level of persistent wage uncertainty. In addition, conditional on switching groups, a worker is more likely to move to Group 3 or 4 than Group 1 or 2. There is also a significant amount of movement between Groups 3 and 4 which is mainly driven by switching between the natural resource extraction and construction industries and between the retail trade, wholesale trade, and other services industries.

3. Model

In this section, a general equilibrium, incomplete markets, life cycle model is developed that captures some of the key trade-offs workers face when deciding in which industry to employ their skills. In the following section, the model is taken to the data in order to evaluate its ability to explain the empirical facts described in the preceding section.

3.1. Environment

The economy consists of overlapping generations of ex ante identical workers with time separable preferences over consumption and leisure. Workers live for T periods, the first N of which they are permitted to work, while the remainder represent retirement. The only asset available to workers is a one-period pure discount bond. There are J spatially separated islands, each representing an industry and containing a representative firm that uses labor to produce a differentiated intermediate good. Intermediate goods producers vary in their equilibrium real wage rate, denominated in units of the consumption good per efficiency unit of labor, and the volatility of idiosyncratic productivity shocks that workers face. A representative firm combines intermediate goods with capital to produce a homogeneous final consumption good.

3.2. Timing

The timing of decisions within each model period is illustrated in Fig. 3. At the start of each period, workers age $a \le N$ draw an idiosyncratic permanent shock $\zeta_j \sim N\left(-\frac{1}{2}\sigma^2_{\zeta_j}, \sigma^2_{\zeta_j}\right)$ to their labor productivity z_{-1}, the mean and volatility of which vary exogenously by island of employment j. Conditional on their post-shock labor productivity $z = z_{-1} + \zeta_j$, workers decide whether to remain on their current island of employment j or buy an option that gives them the right, but not the obligation, to switch islands. Workers who buy this option first pay an age-dependent utility cost $\chi(a)$, then select one target island $m \ne j$ on which to search for employment, and finally draw their potential labor productivity on island m, $\hat{z} \sim N(\rho z, \sigma_{\hat{z}})$. The utility cost $\chi(a)$ captures search effort (filling out applications, completing additional training, sitting for pre-screening exams, interviewing with potential employers, etc.), while the realization of $\hat{z}$ represents an offer for employment on island m. The parameter $\rho \in [0, 1]$ governs the transferability of labor productivity between islands, while the parameter $\sigma_{\hat{z}}$ controls the uncertainty workers have about their potential labor productivity on islands $m \ne j$. Conditional on the realization of $\hat{z}$, workers decide whether to exercise their option (switch from island j to island m) or to allow their option to expire (remain on island j). After deciding on which island to supply their labor, workers draw an idiosyncratic transitory labor productivity shock $e_j \sim N\left(-\frac{1}{2}\sigma^2_{e_j}, \sigma^2_{e_j}\right)$, the mean and volatility of which vary exogenously across islands. Finally, workers make labor-leisure and consumption-savings decisions.

3.3. Problem of a worker

Workers have preferences over bundles of consumption and leisure which can be represented by the utility function

$$u(c, l) = \frac{\left(c^{\nu} l^{1-\nu}\right)^{1-\gamma}}{1-\gamma}, \tag{9}$$

where γ is the coefficient of relative risk aversion and the parameter ν governs expenditures on consumption relative to leisure.

The value of a worker of age $a \le N$ with assets b and labor productivity z on island j is

$$V^a_j(b, z) = \max\left\{ \mathbb{E}_e\left[W^a_j(b, z, e)\right], \max_{m \ne j} \mathbb{E}_{\hat{z}}\left[X^a_{j,m}(b, z, \hat{z})\right] - \chi(a) \right\}, \tag{10}$$

where the outer max operator represents the decision of whether or not to buy the option to switch islands and the inner max operator represents the decision of which island $m \ne j$ to target conditional on purchasing this option. The value of having the option to switch from island j to m, conditional on the realization of $\hat{z}$ (labor productivity on island m) is

$$X^a_{j,m}(b, z, \hat{z}) = \max\left\{ \mathbb{E}_e\left[W^a_j(b, z, e)\right], \mathbb{E}_e\left[W^a_m(b, \hat{z}, e)\right] \right\}. \tag{11}$$

Finally, the value of working on island j, conditional on the realization of the idiosyncratic transitory labor productivity shock e, is

$$W^a_j(b, z, e) = \max_{l \in [0,1], b' > \tilde{b}^a_j(z)} u(c, l) + \beta \mathbb{E}_{z'}\left[V^{a+1}_j(b', z')\right] \tag{12}$$

subject to

$$c + \frac{b'}{1+r} = b + w_j(1-l)\exp\left[f(a) + z + e\right], \tag{13}$$

where $z' = z + \zeta_j$, $f(a) = \theta_1 a + \theta_2 a^2 (10)^{-2}$, r is the real interest rate, and w_j is the real wage on island j. Both labor productivity shocks are assumed to have bounded support which, combined with the restriction that $b' > 0$ for $a \geq N$, leads to the natural borrowing constraint $\tilde{b}_j^a(z)$, which varies with age a, island of employment j, and labor productivity z.

Retired workers ($a > N$) simply decide how much of their assets b to consume. The value of being retired is

$$V^a(b) = \max_{b' > 0} u\left(b - \frac{b'}{1+r}, 1\right) + \beta V^{a+1}(b'), \tag{14}$$

where the terminal value is $V^T(b) = u(b, 1)$.

While the problem of a worker must be solved numerically, its key properties can be derived analytically for the case in which $\rho = 0$.[17] First, the expected value of working on any given island j is increasing in a worker's idiosyncratic labor productivity z.

Lemma 1. *$\forall a \in \{1, \dots, N\}$, $b \in \mathbb{R}$, and $j \in \{1, \dots, J\}$, $\mathbb{E}_e\left[W_j^a(b, z, e)\right]$ is strictly increasing in z.*

An implication of Lemma 1 is that a worker who purchases the option to switch islands decides whether or not to exercise this option based on the realization of $\hat{z}$. Since the expected value of remaining on island j, $\mathbb{E}_e\left[W_j^a(b, z, e)\right]$, is independent of $\hat{z}$ while the expected value of switching to island m, $\mathbb{E}_e[W_m^a(b, \hat{z}, e)]$, is strictly increasing in $\hat{z}$ by Lemma 1, there exists a threshold $\hat{z}^*$ for which the value of exercising the option is equal to the value of allowing the option to expire. If $\hat{z}$ exceeds $\hat{z}^*$, then the value of switching to island m is higher than the value of remaining on island j. Proposition 1 formalizes this property of the model.

Proposition 1. *$\forall a \in \{1, \dots, N\}$, $b \in \mathbb{R}$, $z \in \mathbb{R}$, $j \in \{1, \dots, J\}$, and $m \in \{1, \dots, J\}$, $\exists \hat{z}^* \in \mathbb{R} \cup -\infty \cup \infty$ such that if $\hat{z} > \hat{z}^*$, the worker will switch islands, while if $\hat{z} < \hat{z}^*$, the worker will remain on island j.*

The next lemma states that the threshold $\hat{z}^*$ is increasing in a worker's labor productivity on their current island of employment, z.

Lemma 2. *$\forall$ $a \in \{1, \dots, N\}$, $b \in \mathbb{R}$, $j \in \{1, \dots, J\}$, and $m \in \{1, \dots, J\}$, the threshold $\hat{z}^*$ is increasing in z.*

In other words, the more productive a worker is on their current island of employment, the higher is their reservation productivity for deciding to switch islands. Given Lemma 2, the following proposition states that the decision of whether or not to purchase the option to switch islands also follows a simple threshold rule.

Proposition 2. *Suppose $\rho = 0$. Then $\forall a \in \{1, \dots, N\}$, $b \in \mathbb{R}$, and $j \in \{1, \dots, J\}$, $\exists z^* \in \mathbb{R} \cup -\infty \cup \infty$ such that if $z < z^*$, the worker will purchase the option to switch islands, while if $z \geq z^*$, the worker will not purchase the option to switch islands.*

The intuition for this result is as follows. If $\rho = 0$, then $\hat{z} \sim N(0, \sigma_{\hat{z}})$ and therefore the value of exercising the option is independent of z. The value of remaining on island j, however, is strictly increasing in z by Lemma 1. It follows that the value of buying the option to switch islands is decreasing in z, meaning that only workers who realize a sufficiently adverse persistent labor productivity shock will find it optimal to buy the option to switch islands.

3.4. Intermediate goods producers

The representative firm on island j produces a differentiated intermediate good according to a technology that is linear in efficiency units of labor L_j. The firm chooses L_j to maximize their static profits π_j taking the real wage w_j and the price of output p_j as given:

$$\max_{L_j} \pi_j(L_j) = \max_{L_j} p_j x_j - w_j L_j, \tag{15}$$

subject to the production function

$$x_j = L_j. \tag{16}$$

The first order condition for profit maximization implies that $w_j = p_j$ in equilibrium.

3.5. Final goods producer

A representative firm produces a homogeneous final consumption good using capital rented from workers and a CES aggregation of the differentiated intermediate goods produced on islands $j \in \{1, \dots, J\}$. The firm chooses K and $\{X_j\}_{j=1}^J$ to maximize its static profits Π taking the real interest rate r and the prices of intermediate goods $\{p_j\}_{j=1}^J$ as given:

$$\max_{K, \{X_j\}_{j=1}^J} \Pi\left(K, \{X_j\}_{j=1}^J\right) = \max_{K, \{X_j\}_{j=1}^J} Y - (r + \delta)K - \sum_{j=1}^{J} p_j X_j, \tag{17}$$

[17] All proofs are collected in the supplementary material.

subject to the production function

$$Y = K^{\alpha}\left(\sum_{j=1}^{J} X_j^{1-1/\eta}\right)^{(1-\alpha)/(1-1/\eta)}, \tag{18}$$

where δ is the depreciation rate of capital, α is the share of total income paid to capital, and η is the elasticity of substitution between intermediate goods. The first order conditions for profit maximization pin down the equilibrium values of r and $\{p_j\}_{j=1}^{J}$.

3.6. Market clearing

Let $\Gamma(b,z,e;a,m)$ be the distribution of workers over states after the island switching process is complete and workers have drawn their idiosyncratic island-specific transitory productivity shocks. There are markets for labor on each island, capital, intermediate goods, and the final consumption good, all of which must clear in equilibrium.

The market clearing condition for labor on each island $j \in \{1,\ldots,J\}$ is given by

$$\int [1-l(b,z,e;a,m)]\exp[f(a)+z+e]\mathbb{I}_{m=j}\, d\Gamma(b,z,e;a,m) = L_j, \tag{19}$$

where $\mathbb{I}_{m=j}$ is an indicator function that is equal to one if a worker is employed on island j, and zero otherwise. This condition states that the total efficiency units of labor supplied by workers on island j must equal the total efficiency units of labor demanded by the representative firm on island j. The real wages $\{w_j\}_{j=1}^{J}$ adjust to clear the market for labor on each island.

The market clearing condition for the capital rental market is given by

$$\int b'(b,z,e;a,m)\, d\Gamma(b,z,e;a,m) = K. \tag{20}$$

The real interest rate r adjusts to clear this market.

The market for each intermediate good $j \in \{1,\ldots,J\}$ clears when the quantity produced by the representative firm on island j is equal to the quantity demanded by the final goods producer:

$$X_j = x_j. \tag{21}$$

The prices of intermediate goods $\{p_j\}_{j=1}^{J}$ adjust to clear the markets for intermediate goods.

Finally, the market for the final consumption good clears when the aggregate quantity demanded by workers, plus the replacement of depreciated capital by the final goods producer, is equal to aggregate output:

$$\int c(b,z,e;a,m)\, d\Gamma(b,z,e;a,m) + \delta K = Y. \tag{22}$$

The market for the final consumption good clears by Walras' Law provided all budget constraints are satisfied and the markets for labor, capital, and intermediate goods clear.

3.7. Definition of a competitive equilibrium

A competitive equilibrium consists of policy rules for workers, intermediate goods producers, and the final goods producer, real wages and output prices on each island, a real interest rate, and a distribution of workers over states such that, given prices, each worker is optimized, each intermediate goods producer is maximizing profits, the final goods producer is maximizing profits, and the markets for labor, capital, and intermediate goods clear.

4. Quantitative results

In this section, the theoretical model developed in Section 3 is taken to the data. The fitted model's predictions for the relationships between wage differentials, wage uncertainty, returns to tenure, and mobility are then compared to the empirical facts documented in Section 2.

4.1. Calibration

Workers are born at age 19 with zero assets and labor productivity normalized to zero, retire at age 65, and die with probability one at age 78. Each model period represents one calendar year, and therefore $N=46$ and $T=60$. As is standard in the literature, the discount factor β is set equal to 0.96, capital's share of total income α is set equal to 0.33, and the depreciation rate of capital δ is set equal to 0.06. Following Hsieh et al. (2013), the elasticity of substitution between intermediate goods η is set equal to 4. The economy contains four islands ($J=4$), each corresponding to one of the industry groups described in Section 2.4. Workers are randomly assigned to islands at birth with probabilities $\{\phi_j\}_{j=1}^{J}$ chosen to match the distribution of 19 year olds across industry groups reported in Table 3.

The remaining model parameters are jointly selected using a combination of indirect inference and simulated method of moments. These include the island-specific labor productivity shock volatilities $\{\sigma_{\zeta,j}\}_{j=1}^{J}$ and $\{\sigma_{e,j}\}_{j=1}^{J}$, preference parameter ν, coefficient of relative risk aversion γ, age-earnings profile coefficients θ_1 and θ_2, utility cost of the option to switch islands χ (a), and parameters that govern the distribution of labor productivity draws for workers who buy the option to switch islands ρ and $\sigma_{\hat{z}}$. Proposition 2 implies that workers who receive a sufficiently adverse labor productivity shock will purchase the option to switch islands. As a result, estimates of $\hat{\sigma}^{b}_{\zeta,j}$ and $\hat{\sigma}^{b}_{e,j}$ using data only for individuals who do not switch industries will suffer from selection bias. Indirect inference is used to control for selection effects. In particular, $\{\sigma_{\zeta,j}\}_{j=1}^{J}$ and $\{\sigma_{e,j}\}_{j=1}^{J}$ are chosen such that estimates of the biennial shock volatilities $\{\hat{\sigma}^{b}_{\zeta,j}\}_{j=1}^{J}$ and $\{\hat{\sigma}^{b}_{e,j}\}_{j=1}^{J}$ using simulated data match the corresponding estimates reported in Table 3, after adjusting for measurement error.[18] The preference parameter ν is chosen such that the average time spent working in the model matches the corresponding statistic in the data. The coefficient of relative risk aversion γ controls the strength of the risk effect relative to the option effect, and is therefore selected such that the coefficient on $\hat{\sigma}^{b}_{\zeta,j}$ in a cross-industry regression of $\hat{\Omega}_j$ on $\hat{\sigma}^{b}_{\zeta,j}, \hat{\sigma}^{b}_{e,j}$, and a constant using simulated data matches the corresponding estimate reported in Column (1) of Table 2. The coefficients of the age-earnings profile θ_1 and θ_2 are chosen such that the corresponding estimates obtained from an OLS regression of Eq. (1) using simulated data match those obtained using PSID data. The utility cost of buying the option to switch islands χ (a) is intimately related to equilibrium rates of inter-industry mobility, and therefore χ (a) is selected such that the model matches the biennial inter-industry mobility rate by age depicted in Fig. 1. The parameters ρ and $\sigma_{\hat{z}}$ also impact equilibrium rates of inter-industry mobility. In particular, larger values of ρ imply that $\hat{z}$ depends more on a worker's current labor productivity, which reduces the insurance value that mobility provides against adverse persistent labor productivity shocks. Furthermore, increasing $\sigma_{\hat{z}}$ raises the speculative value of buying the option to switch islands. However, ρ and $\sigma_{\hat{z}}$ are separately identified using the mean and standard deviation of wage growth for industry-switchers. To see why, first note that wage growth for industry-switchers in the model is determined by the difference between their current labor productivity z and the realization of $\hat{z}$. By construction, the mean of $\hat{z}$ is ρz, and therefore the mean of $\hat{z}-z$ converges to 0 as ρ approaches 1. Moreover, for any given z and ρ, the standard deviation of $\hat{z}-z$ is increasing in $\sigma_{\hat{z}}$. However, Proposition 1 implies that workers will only exercise the option to switch islands for sufficiently high realizations of $\hat{z}$. Here again, indirect inference is used to control for selection bias. Specifically, the parameters ρ and $\sigma_{\hat{z}}$ are chosen such that the mean and standard deviation of wage growth for industry-switchers in simulated data matches the corresponding estimates in the PSID.

4.2. Model fit

The results of this calibration exercise are summarized in Table 5. In terms of non-targeted moments, the fitted model has sharp predictions for the relationships between wage uncertainty, returns to industry tenure, and patterns of inter-industry mobility. While wage risk varies exogenously across islands in the model, returns to industry tenure and patterns of inter-industry mobility are each endogenously determined in equilibrium

Consistent with the empirical facts documented in Table 2, the fitted model endogenously generates a positive correlation between the level of persistent wage uncertainty and rates of inter-industry mobility. The reason for this is that workers on islands with highly volatile persistent labor productivity shocks are more likely to purchase and exercise the option to switch islands. Since workers only purchase and exercise the option to switch islands in response to adverse labor productivity shocks, conditional on island tenure, workers employed on islands with relatively volatile persistent productivity shocks will be more productive, on average, than their peers. As a result, the fitted model also generates a positive correlation between the level of persistent wage volatility and returns to industry tenure, as in the data.

Panels (a) and (b) of Table 4 compare the model-generated inter-island transition matrix to its empirical counterpart. While the model under-predicts the persistence of industry group affiliation and over-predicts the frequency of movement between industry groups 1 and 2, it does an excellent job of matching the observed probability of switching between industry groups 3 and 4, as well as the inverse relationship between the level of persistent wage uncertainty and the persistence of industry group affiliation.

Fig. 2(a) and (b) compares the fraction of workers employed on each island by age in the fitted model to its empirical counterpart in the data. The fitted model excels along this particular dimension, as it is able to endogenously replicate the broad patterns of net mobility between industry groups over the life cycle observed in the data. This result is driven by (1) the exogenous distribution of 19 year olds across islands and (2) an endogenous decline in the option value of switching islands with age. More specifically, 19 year olds in the data disproportionately seek employment in industries with higher than average persistent wage uncertainty. Moreover, young workers value exposure to persistent wage uncertainty more than their older counterparts since they have more time before retirement to either realize large productivity gains, or purchase and exercise the option to switch islands. The positive relationship between persistent wage uncertainty and mobility rates implies that the option value of inter-industry mobility is increasing in the volatility of the persistent labor productivity shocks that workers

[18] Bound et al. (1994) find that about 22% of the variance in earnings growth in the PSID is explained by measurement error.

Table 5
Parameters, calibration targets, and model fit.

Parameters calibrated outside of the model		
Years of working life, N		46
Years of retirement, R		14
Number of islands, J		4
Discount factor, β		0.96
Depreciation rate of capital, δ		0.06
Share of total income paid to capital, α		0.33
Elasticity of substitution between intermediates, η		4
Initial distribution of workers across islands, $\{\phi_j\}_{j=1}^J$		0.193, 0.219, 0.369, 0.219
Parameters calibrated to match targets		
Volatility of persistent wage shocks, $\{\sigma_{\zeta,j}\}_{j=1}^J$		0.095, 0.110, 0.122, 0.140
Volatility of transitory wage shocks, $\{\sigma_{e,j}\}_{j=1}^J$		0.115, 0.117, 0.119, 0.115
Coefficient of relative risk aversion, γ		5.69
Preference parameter, ν		0.388
Utility cost of the option to switch islands, $\chi(a)$		see Supplemental Material
Age-earnings profile coefficients, $\{\theta_1, \theta_2\}$		0.050, −0.047
Weight on current productivity for switchers, ρ		0.81
Volatility of persistent wage shock for switchers, σ_ε		0.022
Calibration targets	**Model**	**Data**
Volatility of persistent wage shocks, $\{\hat{\sigma}^b_{\zeta,j}\}_{j=1}^J$	0.128, 0.143, 0.161, 0.180	0.128, 0.144, 0.159, 0.180
Volatility of transitory wage shocks, $\{\hat{\sigma}^b_{e,j}\}_{j=1}^J$	0.116, 0.119, 0.120, 0.119	0.117, 0.118, 0.121, 0.119
Coefficient on $\hat{\sigma}^b_{\zeta,j}$ in regression of $\hat{\Omega}_j$ on $\hat{\sigma}^b_{\zeta,j}$, $\hat{\sigma}^b_{e,j}$	−1.31	−1.34
Fraction of time spent working	0.39	039
Biennial inter-industry mobility rate by age	see Fig. 1	see Fig. 1
Estimated age-earnings profile coefficients, $\{\hat{\theta}_1, \hat{\theta}_2\}$	0.048, −0.051	0.048, −0.051
Mean of $g_{i,j,t}$ for island switchers	0.045	0.040
Standard deviation of $g_{i,j,t}$ for island switchers	0.30	0.36
Other statistics	**Model**	**Data**
Fraction of total observations	0.243, 0.247, 0.255, 0.255	0.246, 0.256, 0.240, 0.258
Estimated inter-island wage differentials, $\{\hat{\Omega}_j\}_{j=1}^J$	0.037, 0.016, −0.026, −0.025	0.076, −0.001, −0.052, −0.029
Estimated returns to tenure, $\{\hat{\Psi}_j\}_{j=1}^J$	0.019, 0.021, 0.023, 0.025	0.004, 0.006, 0.005, 0.011
Biennial inter-industry mobility rate, $\{m_j\}_{j=1}^J$	0.158, 0.180, 0.177, 0.190	0.163, 0.139, 0.203, 0.219
Inter-island efficiency wage differential, $\{\omega_j\}_{j=1}^J$	0.016, 0.004, −0.005, −0.014	n/a

face. As a result, young workers disproportionately seek employment in industries with higher than average wage volatility. As they accumulate labor market experience, however, those who realize positive persistent labor productivity shocks will stay, while those who do not will optimally decide to seek employment in other industries characterized by lower levels of persistent wage uncertainty. The result is a large mass of workers who initially seek employment on islands 3 and 4, and then migrate to islands 1 and 2 in response to adverse persistent labor productivity shocks.

4.3. Implications for the industry wage structure

The fitted model allows for a simple decomposition of the inverse empirical relationship between inter-industry wage differentials and persistent wage uncertainty into three components: (1) compensating differentials determined by the relative magnitude of the risk and option effects, (2) systematic sorting across industries over the life cycle based on unobservable characteristics, and (3) selection bias in estimates of persistent wage uncertainty.

The extent to which this empirical relationship reflects compensating differentials arising from variations in wage uncertainty across industries is determined by the relative magnitude of the risk and option effects. On one hand, since workers are risk averse and cannot perfectly insure themselves against persistent labor productivity shocks, they demand a premium for exposure to excess levels of persistent wage uncertainty. On the other hand, as long as idiosyncratic labor productivity shocks are not perfectly correlated across industries, exposure to high levels of persistent wage uncertainty provides the opportunity for rapid wage growth with limited downside risk. The distribution of real wages across islands $\{w_j\}_{j=1}^4$, expressed in units of consumption per efficiency unit of labor and reported in Table 5, reflects the result of a horse race between these two opposing forces. The coefficient on $\sigma_{\zeta,j}$ in an OLS regression of w_j on $\sigma_{\zeta,j}\sqrt{2}, \sigma_{e,j}\sqrt{2}$, and a constant using model-generated data is

-0.46.[19] This result implies that the option effect dominates the risk effect in equilibrium – for every 1% *increase* in within-industry idiosyncratic persistent wage uncertainty that a worker accepts, their expected wage *decreases* by 0.46%.[20]

Since labor productivity is unobservable to the econometrician, industry-level fixed effects estimated via OLS regression of Eq. (1) reflect both compensating differentials and systematic sorting across industries over the life cycle on labor productivity. To understand why, recall that while there are no exogenous returns to industry tenure in the fitted model, estimated returns to tenure arise due to the endogenous inter-industry mobility decisions of workers – those who realize sufficiently adverse persistent labor productivity shocks buy and exercise the option to switch islands, which means that average labor productivity is increasing in industry tenure. This effect leads to measured returns to tenure in an OLS regression of Eq. (1) using simulated data. Moreover, these measured returns to tenure are increasing in the volatility of the persistent labor productivity shocks that workers face. Fig. 4 depicts the average labor productivity of workers by island of employment over the life cycle. Variations in persistent wage uncertainty, coupled with endogenous mobility decisions, lead to stark differences across islands in average labor productivity by age. Returns to tenure and the error term in Eq. (1) are thus positively correlated, which introduces bias into estimates of the industry wage structure. Given that the real wages $\{w_j\}_{j=1}^4$ solely reflect compensating differentials, differences between $\{\hat{\Omega}_j\}_{j=1}^4$ and $\{w_j\}_{j=1}^4$ arise as a result of systematic sorting across industries over the life cycle on labor productivity. Using simulated data, the coefficient on $\sigma_{\zeta,j}\sqrt{2}$ in an OLS regression of $\hat{\Omega}_j$ on $\sigma_{\zeta,j}\sqrt{2}, \sigma_{e,j}\sqrt{2}$, and a constant is -1.07. Thus, this bias works to steepen the measured trade-off between risk and return across industries.

Finally, selection bias in estimates of within-industry persistent wage uncertainty accounts for the remaining difference between the model-implied and empirically observed relationship between the level and volatility of wages across industries. Recall that selection bias arises from the use of data for industry-stayers in estimating $\sigma^b_{\zeta,j}$ via Eqs. (7) and (8). The fitted model yields selection corrected estimates of $\sigma^b_{\zeta,j}$, namely $\sigma_{\zeta,j}\sqrt{2}$. Comparing these values implies that selection bias leads to empirical estimates of persistent wage uncertainty that are too low by an average of 7.4%. Moreover, the magnitude of selection bias is increasing in the volatility of the persistent labor productivity shocks that workers face.[21] In the model, this relationship arises because higher persistent wage volatility leads to higher mobility rates, which then increases the importance of selection effects. As a result, selection bias reduces the observed variation in persistent wage uncertainty across industries, causing the estimated trade-off between risk and return to steepen further.

4.4. *The option value of inter-industry mobility*

Like precautionary savings and variation in labor supply, the ability to switch industries in response to an adverse persistent labor productivity shock serves as an insurance channel against labor market risk. In order to quantify the welfare gains workers derive from inter-industry mobility, the fitted model is compared to a counter-factual economy in which workers are restricted to their initial island of employment from entry into the labor force until retirement. Hence, in this counter-factual economy, the only tools available for self-insurance against labor market risk are precautionary savings and variations in labor supply. All else equal, a comparison between these two economies reveals that workers would be willing to give up 3.3% of their expected lifetime consumption in exchange for the option to switch islands in response to adverse labor productivity shocks. Thus, inter-industry mobility is a quantitatively important insurance channel against labor market risk, providing welfare gains that are more than an order of magnitude larger than the potential welfare gains from eliminating business cycles estimated by Lucas (1987).

5. Concluding remarks

This paper studies, from both empirical and theoretical perspectives, the risk-return trade-off workers face when deciding in which industry to employ their skills. In particular, it provides direct empirical evidence that the level and volatility of wages vary inversely across industries and offers an equilibrium theory of sorting across industries over the life cycle that is able to account for this feature of the data. A fitted version of the model developed here is also consistent with the empirically observed relationships between wage uncertainty, returns to industry tenure, and patterns of inter-industry mobility over the life cycle.

The fitted model implies that the welfare gains workers derive from being able to switch industries in response to adverse labor productivity shocks are quite large. This finding potentially has important policy implications. In particular, it suggests that policies aimed at reducing mobility costs, such as permitting workers who switch employers to keep their health insurance and deduct reasonable moving expenses from federal taxable income, might have significant positive

[19] In order to be able to directly compare the fitted model's implications to the data, the annual volatility parameters estimated using the fitted model are multiplied by $\sqrt{2}$ thereby converting them to a biennial basis.

[20] The option effect dominates as long as workers are not too risk averse. See the supplementary material.

[21] The fitted model predicts that the magnitude of selection bias for industry groups 1, 2, 3, and 4 is 4.8%, 7.6%, 7.9%, and 9.1%, respectively. Recall that industry group 1 has the lowest persistent wage uncertainty, while industry group 4 has the highest. Critically, while selection biases down estimates of wage volatility, it does not change the relative ranking of industries. As a robustness check, a Heckman selection model is also employed to obtain selection corrected estimates of $\sigma^b_{\zeta,j}$. The average selection bias implied by this exercise is 5.1%, compared to 7.4% using the fitted model. See the supplementary material for details.

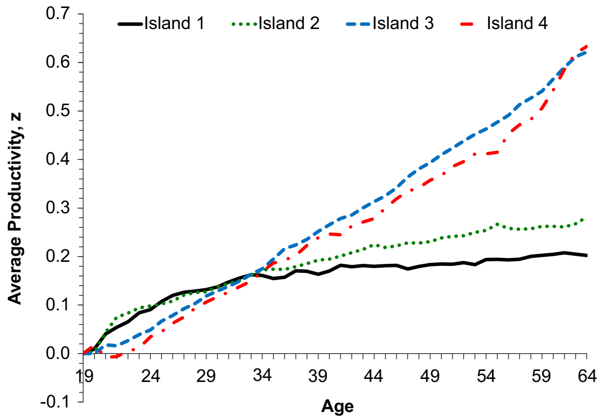

Fig. 4. Average labor productivity z by island of employment in the calibrated life cycle model. The industries represented by each island are: (1) communications and utilities; machinery; metals; other manufacturing; transportation, (2) chemicals, refining, rubber, and plastics; education; food and kindred products; motor vehicle and transport equipment; public administration, (3) construction; professional and related services; retail trade, and (4) finance, insurance, and real estate; health services; natural resource extraction; other services; wholesale trade.

effects on welfare. Similarly, other policies which reduce "job lock" – such as portable 401(k) pension schemes or the health care exchanges set up by the Affordable Care Act – are likely to have larger benefits than a narrow analysis might suggest.

Acknowledgments

I am particularly indebted to Lee Ohanian, Pierre-Olivier Weill, and Andrew Atkeson for the valuable advice they provided throughout this project. I would like to thank Maria Casanova, Francois Gourio, Kyle Herkenhoff, Matthew Luzzetti, Carolina Mejia, Casey Rothschild, Carl Sandberg, Daniel Sichel, Mark Wright, and an anonymous referee for their helpful comments and suggestions. The feedback of numerous seminar participants is also gratefully acknowledged. All remaining errors are my own.

Appendix A. Supplementary data

Supplementary data associated with this paper can be found in the online version at http://dx.doi.org/10.1016/j.jmoneco.2015.08.001.

References

Abowd, J.M., Ashenfelter, O., 1981. Anticipated unemployment, temporary layoffs, and compensating wage differentials. In: Studies in Labor Markets. NBER, pp. 141–186.
Bound, J., Brown, C., Duncan, G.J., Rodgers, W.L., 1994. Evidence on the validity of cross-sectional and longitudinal labor market data. J. Labor Econ. 12 (3), 345–368.
Bulow, J.I., Summers, L.H., 1986. A theory of dual labor markets with application to industrial policy, discrimination, and Keynesian unemployment. J. Labor Econ. 4 (3), 376–414.
Caju, P.D., Kátay, G., Lamo, A., Nicolitsas, D., Poelhekke, S., 2010. Inter-industry wage differentials in E.U. countries: what do cross-country time varying data add to the picture? J. Eur. Econ. Assoc. 8 (2–3), 478–486, 04–05.
Carroll, C.D., Samwick, A.A., 1997. The nature of precautionary wealth. J. Monet. Econ. 40 (September (1)), 41–71.
Cubas, G., Silos, P., 2012. Comparative Advantage and Risk Premia in Labor Markets. Federal Reserve Bank of Atlanta Working Paper 2012-15, October.
Dickens, W.T., Katz, L.F., 1987. Inter-Industry Wage Differences and Theories of Wage Determination. NBER Working Papers 2271. National Bureau of Economic Research, Inc.
Dynan, K., Elmendorf, D., Sichel, D., 2012. The evolution of household income volatility. B.E. J. Econ. Anal. Policy 12 (December (2)), 1–42.
Gibbons, R., Katz, L.F., 1992. Does unmeasured ability explain inter-industry wage differentials? Rev. Econ. Stud. 59 (July (3)), 515–535.
Gourieroux, C., Monfort, A., Renault, E., 1993. Indirect inference. J. Appl. Econom. 8 (S), S85–118.
Harris, M., Weiss, Y., 1984. Job matching with finite horizon and risk aversion. J. Polit. Econ. 92 (4), 758–779.
Heathcote, J., Storesletten, K., Violante, G.L., 2008. Insurance and opportunities: a welfare analysis of labor market risk. J. Monet. Econ. 55 (3), 501–525.
Hsieh, C.-T., Hurst, E., Jones, C.I., Klenow, P.J., 2013. The Allocation of Talent and U.S. Economic Growth. NBER Working Papers 18693, January.
Johnson, W.R., 1978. A theory of job shopping. Q. J. Econ. 92 (May (2)), 261–278.
Jovanovic, B., 1979. Job matching and the theory of turnover. J. Polit. Econ. 87 (October (5)), 972–990.
Kambourov, G., Manovskii, I., 2008. Rising occupational and industry mobility in the United States: 1968–97. Int. Econ. Rev. 49 (1), 41–79, February.
Kambourov, G., Manovskii, I., 2013. A cautionary note on using (march) current population survey and panel study of income dynamics data to study worker mobility. Macroecon. Dyn. 17 (January (01)), 172–194.
Kaplan, G., 2012. Moving back home: insurance against labor market risk. J. Polit. Econ. 120 (June (3)), 446–512.
Krueger, A.B., Summers, L.H., 1988. Efficiency wages and the inter-industry wage structure. Econometrica 56 (March (2)), 259–293.
Lagakos, D., Ordonez, G.L., 2011. Which workers get insurance within the firm? J. Monet. Econ. 58 (6), 632–645.
Lucas, R.E., 1987. Models of Business Cycles, vol. 26. Basil Blackwell, Oxford.

Lucas, R.J., Prescott, E.C., 1974. Equilibrium search and unemployment. J. Econ. Theory 7 (February (2)), 188–209.
Meghir, C., Pistaferri, L., 2004. Income variance dynamics and heterogeneity. Econometrica 72 (1), 1–32. 01.
Miller, R.A., 1984. Job matching and occupational choice. J. Polit. Econ. 92 (December (6)), 1086–1120.
Moore, J.C., 2008. Seam Bias in the 2004 Sipp Panel: Much Improved, But Much Bias Still Remains. US Census Bureau Statistical Research Division Survey Methodology Research Report Series 3.
Murphy, K., Topel, R., 1987. Unemployment, risk, and earnings: testing for equalizing wage differences in the labor market. In: Lang, K., Leonard, J. (Eds.), Unemployment and the Structure of Labor Markets. Basil Blackwell, London.
Rosen, S., 1986. The theory of equalizing differences. In: Ashenfelter, O., Layard, R. (Eds.), Handbook of Labor Economics, vol. 1, 1st edn. Elsevier, pp. 641–692 (Chapter 12).
Smith Jr., Anthony A., 1993. Estimating nonlinear time-series models using simulated vector autoregressions. J. Appl. Econom. 8 (S), S63–84, Suppl. De.
Stiglitz, J.E., 1986. Theories of Wage Rigidity. NBER Working Paper 1442, June.
Vereshchagina, G., Hopenhayn, H.A., 2009. Risk taking by entrepreneurs. Am. Econ. Rev. 99 (December (5)), 1808–1830.
Viscusi, W.K., 1980. A theory of job shopping: a Bayesian perspective. Q. J. Econ. 94 (May (3)), 609–614.