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Derived demand shifts, on-the-job training, and labor market dynamics: A theoretical and empirical analysis

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DERIVED DEMAND SHIFTS, ON-THE-JOB TRAINING, AND LABOR MARKET DYNAMICS: A THEORETICAL AND EMPIRICAL ANALYSIS

by

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Chapter I

The purpose of this dissertation is to analyze wage changes and job turnover of an individual worker by combining the derived demand for labor (DDL) with the human capital investment (HCI) hypothesis. That is, the dissertation merges the effects of both the labor market and the product market on wage changes, job search and permanent job separations in the context of micro-labor economics. Most existing wage growth or quit models try to explain these topics from the supply side of the labor market or, at least, neglect a firm's situation in the product market (examples include the HCI, job matching and job search models). This dissertation tries to address this weakness in the existing literature. The existing approach to analyze the wage growth and permanent job separations can be summarized as follows.

The HCI models say that as a worker invests in on-the-job training or schooling, the human capital of the worker increases (see Becker (1964) and Mincer (1962)). Independent variables included in the standard earnings function are a worker's years of completed schooling, years of job tenure (representing investment in firm-specific human capital), years of total labor force experience (representing investment in general human capital), and other individual worker-specific characteristics. A current reserach interest in the literature is how the wage-tenure profile can be estimated correctly using panel data. For example, Abraham and Farber (1987), and Altonji and Shakoto (1987) report suprisingly low estimates of tenure effects, which are not consistent with high positive estimates by cross-sectional regressions. The HCI models can explain the wage growth, but these models themselves cannot explain labor mobility well without the help of the job-search models or a large unexpected error term in a worker's productivity equation (see Hashimoto (1979,1981)). The main implications of the models are as follows. Large investments in firm-specific human capital are likely to lead to reduced labor mobility, since the economic cost of permanent job separations is increased. If a worker's value of marginal product in a firm exceeds his wages during normal product demand periods, the firm will be less likely to lay him off even if the faces a minor demand decline. Similarly, a worker who receives a wage higher than the wage he could receive elsewhere will be less likely to quit than otherwise. It is important to separate the worker's specific human capital into firm-financed and worker-financed specific human capital, since the former will more directly influence layoff rates, the latter quit rates. (see Parsons (1972)).

The dominant approach to labor mobility from the demand side of the labor market is the DDL hypothesis. It says that as demand for a firm's product rises relative to that of other firms, the wages of its workers rise. Thus, it attracts workers from other firms and induces them to move to the firm. In the model, reallocation of labor takes place in response to a changing composition of product demand and a changing technology. This approach requires neither heterogeneity of workers nor uncertainty: even if labor and capital were homogeneous, and even if demand shifts and technology shifts were perfectly foreseeable, job turnover would still take place. See Lucas and Prescott (1974). However, this model cannot explain wage differentials among workers in the same firm, and the on-the-job wage growth of an individual worker; especially, why the wages may rise even though output of the firm has been in low demand. Concerning on job turnover, the model cannot explain why the gross flows of labor between industries are so much greater than the net flows (see Bull and Jovanovic (1986)).

The job matching hypothesis, which is developed by Jovanovic (1979, 1984), is powerful and clear in explaining job turnover. This hypothesis starts by assuming that a worker's productivity is determined by the quality of each job matching between a worker and his employer. Then, workers who have better matches with their employers tend to receive higher earnings, have longer job tenure and accumulate more specific human capital than poorly matched workers. This approach relies on heterogeneity of jobs and workers and on incomplete information about the location of the optimal match. However, this approach provides a poor explanation of on-the-job wage growth.

The job search model plays an important role in explaining voluntary job separations in micro-labor ecomnomics. The key idea of this model is the reservation wage property. Mathematically, optimal stopping theory plays an important role. It can explain well the existence of voluntary unemployment in addition to a job-to-job transition. The theoretical model has been developed in past 15 years by many mathematical economists (see Mortensen (1986) for the summary of the literature). Recently, empirical estimations of job search models has become popular (see Kiefer and Neumann (1979)). However, the effects of the product market are neglected in the existing literature.

This dissertation shows that the HCI models can improve the power to explain the wage growth and job turnover by combining the idea of the DDL hypothesis. Both theoretical and empirical analysis are provided in this dissertation. The dissertation is organized as follows.

Chapter II derives the theoretical model of wage dynamics. A stochastic wage process is derived by combining the idea of the HCI and the DDL hypothesis. It explains why a standard HCI model is weak in explaining quit rates and when a worker with a long-run view also compares current wages in his quit-or-stay decision. After deriving some interesting propositions about the wage growth and quit rates, it provides motivation for empirical estimation of the model.

Chapter III estimate the earnings function that is derived in chapter II by merging the Panel Study of Income Dynamics with published data on industry prices and other demand variables pertaining to the industy in which the respondent works. An earnings function is estimated by a two-step procedure. After eliminating macro business cycle effects, the chapter finds that a worker is paid more as industry product demand becomes higher and has more cyclical fluctuations. It also finds that if the product demand variables are eliminated in estimating an earnings function, it will lead to a downward bias in the wage-tenure profile. The statistical technique underlying the estimates is a variance component model.

Chapter IV analyzes the possible censoring problem in the observed wage data. The statistical technique underlying the estimates is maximum-likelihood estimates of the switching-regime model where the switching is endogenously determined. An empirical finding is that a worker's wage rises as his firm's product demand becomes higher even after correcting censoring and/or self-selection bias.

Chapter V estimates a job separation function which includes the demand variables used in chapter III and IV. Interesting empirical findings are that as the product demand in the industry rises and as it has less cyclical fluctuations, a worker tends to stay longer in the same firm. Furthermore, the chapter shows a quit probability is more sensitive to product demand than a layoff probability.

Chapter VI estimates the expected result of job search; that is, whether a worker becomes better off after the completion of his job search process. The chapter estimates the effect of the demand variables in addition to the choice of search methods by a worker (on-the-job search or full-time search) and the reason of permanent job separation (quit or layoff). The statistical technique underlying the estimates is a bivariate probit model. The results suggest that unemployment experience and product demand of a new firm are more important than the type of termination in determining whether a worker becomes better off after changing a job.

CHAPTER II

A Theoretical Analysis of the Wage Growth and Quit Rates

[1] Introduction

The purpose of this chapter is to provide a theoretical model of wage dynamics by combining the derived demand for labor (DDL) approach with the human capital investment (HCI) approach. The main contribution of this chapter is to show the importance of the DDL approach in improving HCI models as the main hypothesis to explain the labor market dynamics. At first, this chapter formulates a stochastic wage process and derives the earnings function that plays a central role in this dissertation. Secondly, the chapter shows that the standard HCI model can improve the power to explain quit rates if it is supplemented by the DDL hypothesis. Thirdly, it provides motivations of empirical work that are estimated in other chapters of this dissertation.

Following Hashimoto (1979), the model presented here considers heterogeneous employers and employees. The productivity of a worker is increased by on-the-job training (OJT). At the begining of each job matching a worker and his employer contract for the amounts and sharing of returns and costs of OJT. This is then fixed during the job tenure. The model assumes that a firm produces one product at a single market price which varies over time. The current values of a firm's relative product price and a worker's productivity are common knowledge. In this contract, the employer makes a wage offer to a worker based on the known current productivity and the firm's product demand. The model assumes perfectly flexible wage contracts against shifts and shocks in the product market. This is different from the usual HCI models that assume all firms face the same product demand. Thus, the present paper does not consider changes in the level of employment (the hiring and layoff decisions of a firm) because of shifts and shocks in the product market. A worker's productivity at other prospective firms is also increased by OJT at his present firm, although the rate of the return is lower than at his present firm. Thus, if the product price drops relative to those of other firms, this may trigger a quit to another firm. The model assumes that both a firm's relative product price and a worker's productivity follow stochastic processes.

After the model of the wage dynamics is provided, this chapter analyzes the optimal quitting time of a present job under the assumption that both the wage at his present firm and the wage at prospective firms follow diffusion processes. A worker is assumed to have a long-run view in the sense that he maximizes the expected present discounted value (PDV) of lifetime wealth. This chapter argues why the usual HCI models are unable to explain quit behavior of a worker well. Furthermore, it explains why the merged model of the job matching hypothesis and the DDL approach cannot explain the quit decision of a worker with a long-run view (see Bull and Jovanovic (1988)).[1] The present model that combines the DDL and the HCI approach is better able to explain their behavior. Furthermore, the model can also explain why a worker tends to work for a firm that provides him an efficient OJT program to raise both firm-specific and general skill, or a firm that gives him a higher share of returns to OJT. These facts as well as the explanation by the job matching and the DDL approach are important when labor mobility within the same industry is analyzed.

This chapter analyzes carefully when a worker who normally compares the PDVs also considers the current wages in his quit-or-stay decision. Novel aspect of this paper is that the PDVs of jobs change sequentially under the assumption of stochastic wage processes. Thus the reservation wage also changes during his job tenure. Although this chapter provides a new analysis of the wage dynamics, on-the-job search and quit rates of workers, it does not consider layoff policy of a firm when it faces falls in its product demand. The techniques used are Ito stochastic differential equations[2] and the optimal stopping rule. The model assumes that both a worker and a firm behave under uncertainty.

This chapter is organized as follows. Section 2 formulates a

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1 The idea of this chapter comes from one by Bull and Jovanovic (1988). They define the wage of a worker by the product of a firm's product price and a match value. They explain labor mobility by merging two causes: shifts in the DDL on the part of the firm and mismatches between workers and their jobs. Their model explains the change of the average wage of the tenure cohort in the firm which is caused by changes in the product price (by what they call the price effect and the selection effect). However, the model cannot explain well on-the-job wage growth of an individual worker; that is, why the wage rises even though output of the firm has been in low demand. Concerning labor mobility, their model can explain well myopic quit and layoff decisions, but it cannot explain well of quit behavior of a worker with a long-run view.

2 Although the assumption of continuous time seems to make the model complicated, it actually does not. It makes our analysis of wage changes and quit rates under uncertainty easier.

worker's stochastic wage process and derives the earnings function that is estimated in chapter III and IV. Then it analyzes the wage changes. Section 3 analyzes quit behavior of a worker with a long-run view. After explaining the weakness of the existing approaches of quit rates, the assumptions and advantages of the model are outlined. Then the reservation wage is derived and quit rates are analyzed carefully. Two cases are considered. The first case is an extension of a usual on-the-job search model. The second is the case where a worker is allowed to receive a replaced job offer from the firm whose job offers he rejected before. This case provides interesting propositions about quit rates. Section 4 provides some concluding remarks.

[2] Derivation of a Stochastic Wage Process

This section presents a simple model of wage dynamics and derives the earnings function that is estimated empirically in chapter III and IV. A stochastic nominal wage process is constructed from a stochastic product price process and a stochastic real wage process. The technique used here is based on Ito stochastic differential equations.[3] A firm is assumed to produce one product at a single market price. The current values of a worker's productivity and his firm's product price are common knowledge. However, the present value of of a job changes in each period because of a stochastic nominal wage process. Thus a worker and his employer have perfect information about the determination process of current wages, but they do not have perfect information about the value of a job. Although a worker, a pure wealth maximizer, is allowed to switch to another firm, the model does not consider possible layoffs because of shifts and shocks in the product market. Whenever a firm's relative product price changes, the wages of its workers vary continuously, as in an auction market, to keep level of employment level constant.

a) Stochastic Product Price Process.

First let us define a firm's product price process. For each firm, a product price follows a Markov diffusion process with transition probability function over an interval $[\underline{p},\overline{p}]$.[3] Consider a probability space (Ω,F,P), where Ω is a nonempty space of trials, F is a σ-field of subsets of Ω representing various events, and P is a probability measure defined on F. Consider the interval [0, T] which can also be $[0, \infty)$. Firm j's stochastic product price process is given by

$$\frac{dp_j}{p_j} = a_j(p_j,t)\, dt + \delta_j(p_j,t)dz, \qquad (1.a)$$

with the initial condition,

3 For a general definition and an interpretation of an Ito stochastic differential equation, see Appendix 1. Although this is the technique that is applied in the finacial economics literature, this is also very useful to define a wage contract.

$$p_j(0) = p_{j0}. \qquad (1.b)$$

where p_j is the product price of firm j, $a_j(p_j,t)$ is the instantaneous expected percentage change in firm j's product price per unit time, z(t) is a standard Wiener process, which is defined for t $\in$ T. dz is distributed iid(0,1) with independent increments so that $cov[z(t),z(t')] = min[t,t']$, and δ_j^2 is the instantaneous variance per unit time. It is interpreted that $a_j(p_j,t)$ is a trend and $\delta_j(p_j,t)$ (> 0) is a cyclical deviation from the trend during time period t.[4] The higher the value of σ_j, the more firm j's product price fluctuates. If $a_j > 1$, firm j is called a growing firm, and if $a_j < 1$, then firm j is a decling firm. A worker uses the value of $a_j(t)$ and $\delta_j(t)$ in his decision regarding whether to quit the firm. No special assumption is made about the situation of firm j in the product market except that firm j's product price follows a Markov diffusion process with an interval $[\underline{p},\overline{p}]$. This assumption is not unreasonable since it is well known that the product price of each firm is different in the short run even in a competitive market. Concerning the product market, worker i is only interested in the current product price and the stochastic product price process of each firm.

Note that equation (1.a) is a AR(1) process since the discrete time version of (1.a) is

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4 If the model assumes that the geometric Brownian motion hypothesis holds for the product prices of firms; that is, $a_j(t)$ and $\sigma_j(t)$ are constants, then the product prices are stationarily and log-normally distributed.

$$p_j(t+1) = p_j(t) + a_j(t)p_j(t) + \delta_j(t)p_j(t)z(t)$$
$$= [1 + a_j(t)]p_j(t) + \delta_j(t)p_j(t)z(t)$$
$$= \theta_j(t)p_j(t) + \Phi_j(t), \qquad (1.c)$$

where $\theta_j(t) = [1 + a_j(t)]$ and $\Phi_j(t) = \delta_j(t)p_j(t)z(t)$, which is an i.i.d. term. If $\theta_j(t) = 1$, that is, $a_j(t) = 0$, then $p_j(t)$ follows a random walk process.

b) Stochastic Real Wage Process.

Let us now define the stochastic productivity process and the stochastic real wage process for a worker. Let $q_{ij}(t)$ be worker i's productivity at firm j in period t. For each worker, the value of q is drawn from the cumulative distribution of workers' productivities. If he switches to another firm, the value of his productivity changes. The model assumes OJT where a worker and his employer contract for the amounts and sharing of returns and costs as usual (see Hashimoto (1979,1981)). Thus, for each job matching, productivity follows a Markov process with the transition probability function with support $[\underline{q},\bar{q}]$, $0<q<q<\infty$. Thus, after the value of productivity is drawn from the distribution, the productivity follows an independent stochastic process. Assume that OJT raises a worker's productivity at other firms as well as his productivity at his present firm.

Assume that $q_{ij}(t)$ increases by the amount of human-capital stock accumulated through investment in OJT. Let

$$q_{ij}(t+1) = q_{ij}(t) + \tau_{ij}\emptyset(t) + q_{ij}(t)z(t) \quad (2.a)$$

with the initial productivity,

$$q_{ij}(0) = q_{ij0} \qquad (2.b)$$

where τ_{ij} is the constant average rate of return to OJT of worker i at firm j, Ø(t) is the amount of OJT, z(t) is a standard Wiener process, being distributed iid(0, t), and $q_{ij}^2(t)t$ is the instantaneous variance.[6] The marginal revenue product of worker i at firm j is given by $p_j(t) \cdot q_{ij}(t)$ in period t.

Worker i's real wage at firm j, $x_{ij}(t)$, is given by the following stochastic process:

$$x_{ij}(t+1) = x_{ij}(t) + \alpha_{ij}\tau_{ij}Ø(t) + x_{ij}(t)z(t) \quad (3.a)$$

with his initial real wage, which is the same as the initial productivity,

$$x_{ij}(0) = x_{ij0} = q_{ij0}, \qquad (3.b)$$

where α_{ij} is a constant fraction representing worker i's share of returns to OJT at firm j. Note that $0 \le \alpha_{ij} \le 1$ and $(1 - \alpha_{ij})$ is the fraction of firm j's share in the return to OJT. $x_{ij}(t+1)$ is normally distributed with mean $x_{ij}(t) + \alpha_{ij}\tau_{ij}Ø(t)$ and with variance

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5 This paper models the uncertainty and randomness of the human capital returns by assuming a Wiener process instead of the usual restrictive multiplicative specification. See Levhari and Weiss (1974) and Eaton and Rosen (1980).

$x^2_{ij}(t)t$. $\alpha_{ij}\tau_{ij}\emptyset(t)$ can be interpreted as an expected net return to OJT for worker i at firm j in period t. Note that the amount of productivity increase through OJT is shared by worker i and firm j since they share the cost of OJT. Thus, the real wage of worker i is always lower than his productivity after OJT has started.[6] In differential form equation (3.a) reads as follows:

$$dx_{ij} = \alpha_{ij}\tau_{ij}\emptyset(t)dt + x_{ij}dz. \quad (4)$$

This is a dynamic version of a usual model of investment in OJT (see, for example, Hashimoto (1979)). Since the rate of return to OJT is larger at the present firm than other prospective firms, the gap between worker i's productivity at firm j and an alternative firm increases so long as that OJT at firm j is continued.[7] Thus his quit probability is a decreasing function of tenure at firm j. Worker i's nominal wage at firm j is defined as follows:

<u>Definition 1</u>: (<u>The Nominal Wage of a Worker</u>)

The nominal wage of worker i at firm j in time period t is defined as $p_j(t)x_{ij}(t) \equiv w_{ij}(t)$.

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6 This is a different from a usual firm-specific human capital model which assume that a firm pays more than a worker's productivity during a training period.

7 If there is no OJT or if a worker pays all the cost of OJT, the real wage of a worker is always equal to his real productivity.

c) Stochastic Nominal Wage Process.

From equation (1.a) and (4), and applying Ito's lemma (see Apppendix 2), worker i's stochastic nominal wage process is derived as follows:

$$dw_{ij} = [a_j(t)p_jx_{ij} + p_j\delta_{ij}\tau_{ij}\emptyset(t) + \delta_j(t)p_jx_{ij}]dt$$
$$+ [\delta_j(t) + 1]p_jx_{ij}dz$$
$$= A_{ij}(t)\ w_{ij}dt + B_{ij}(t)\ w_{ij}dz, \qquad (5.a)$$

with the initial wage of worker i at firm j,

$$w_{ij}(0) = w_{ij0} = p_{j0}q_{ij0} = p_{j0}x_{ij0} \qquad (5.b)$$

where $A_{ij}(t) = [a_j(t) + (\alpha_{ij}\tau_{ij}\emptyset(t)/x_{ij}) + \delta_j(t)]$ (the expected nominal wage growth rate), and $B_{ij}(t) = [\delta_j(t) + 1]$.[8] $(\alpha_{ij}\tau_{ij}\emptyset(t)/x_{ij})$ is interpreted as the expected real wage growth rate of worker i at firm j. Note that $A_{ij}(t)$ is not a constant. Equation (5.a) and (5.b) say that the nominal wage is an increasing function of a firm's product price and OJT. The solution of (5.a) in Ito interpretation is:

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8 When A(t) = A and B(t) = B, a scalar linear Ito stochastic differential equation is called a homogeneous autonomous equation. If this is the case, the following simple equation (compare with equation (5.d)) is derived;

$$w_{ij}(t) = w_{ij}(0)\cdot\exp[(A - 1/2B^2)t + Bz(t)].$$

$$w_{ij}(t) = w_{ij}(0)\cdot\exp\{\int_0^t [A_{ij}(s) - B_{ij}^2(s)/2]ds$$

$$+ \int_0^t B_{ij}(t)dz(t)\}, \qquad (5.c)$$

By taking the expectation of (5.c), the worker i's expected nominal wage at firm j is

$$E[w_{ij}(t)] = E[w_{ij}(0)]\cdot\exp[\int_0^t A_{ij}(s)ds]$$

$$= w_{ij}(0)\cdot\exp[\int_0^t A_{ij}(s)ds].$$

$$= w_{ij}(t-1)\cdot\exp[\int_{t-1}^t A_{ij}(s)ds]. \qquad (6)$$

Equation (6) is a counterpart of a typical earnings function in the micro micro-labor economics literature. It is estimated empirically in chapter III by merging a panel data and published industry prices. The differences from a usual estimation are that equation (6) includes the expected growth rate of a relative product price and the standard deviation of stochastic relative product price process as independent variables in addition to traditional human capital variables.

Whenever a worker considers switching to another firm, he has to calculate the PDV of a job from the information about the initial nominal wage and the expected nominal wage growth rate at the prospective firm. Then he compares it with the PDV of his present job. For details, see Section 3. The following theorem shows that the nominal wage follows a Markov process for each employment:

Theorem 1:

Consider the stochastic differential equation (5.a) with initial condition (5.b) and suppose that a unique solution $w_{ij}(t)$, $t \in [0, T]$ exists. Then $w_{ij}(t)$ is a Markov process[9] whose initial probability distribution at $t = 0$ is w_{ij0} and whose transition probability from w at time period s to w'_{ij} at period t is,

$$P[w'_{ij}(t);\ w_{ij}(s)] = P(w'_{ij}, t | w_{ij}, s). \qquad (7)$$

Proof: See Arnold (1974).

Furthermore, the following theorem is derived:

Theorem 2:

Consider the stochastic differential equation (5.a) with initial condition (5.b) and suppose that a unique solution $w_{ij}(t)$, $t \in [0, T]$ exists. Suppose also that the functions $A_{ij}(t)$ and $B_{ij}(t)$ are continuous with respect to t. Then the solution $w_{ij}(t)$ is a diffusion process with drift coefficient $A_{ij}(t)w_{ij}$ and diffusion coefficient $[B_{ij}(t)w_{ij}]^2$.

Proof: See Arnold(1974) for a formal proof.

This theorem is quite useful and it can be interpreted as follows.

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9 See Malliaris and Brock (1982) for the formal definition of a Markov process.

Suppose a diffusion process is given with coefficients $A_{ij}(t)w_{ij}$ and $[B_{ij}(t)w_{ij}]^2$, then the transition probability $P[w'_{ij},t|w_{ij},s]$ can be calculated from $A_{ij}(t)w_{ij}$ and $[B_{ij}(t)w_{ij}]^2$. That is, if the drift and the diffusion coefficient are known, the probability that a worker's wage changes from w_{ij} to w'_{ij} can be calculated when time changes from s to t. Thus, several states that a worker's wage takes are defined; i.e., by dollar value, the probability of changing from one state to another state can be derived. To understand the meaning of equation (5.a) and (5.b), see Figure 3 in appendix 3. It is well known that a transition probability follows a differential Chapman-Kolmogorov forward equation. See Appendix 4 for details.

Equation (6) becomes the main equation to analyze on-the-job wage growth. If the expression in parentheses in the exponential term is positive, the expected nominal wage of a worker with job tenure t is larger than his initial wage (note that $A_{ij}(t)$ takes either positive and negative values). Futhermore, the following proposition about expected nominal wages in next time period is derived:

Proposition 1:

As the product price of a worker's present firm becomes more cyclically fluctuated, his expected nominal wage rises during the next time period.

Proof: As the value of the nominal wage growth rate rises, his expected wage in next period rises as long as $A_{ij}(t) > 0$. (see equation (5.e)). It follows:

$$\frac{d\ A_{ij}(t)}{d\ \delta_j(t)} = 1 > 0, \qquad (8)$$

Thus as $p_j(t)$ become more cyclically deviated from the trend, the expected nominal wage in next period increases. Q.E.D.

This proposition is intersting since it is testable. However, note that worker i's actual nominal wage does not necessarily rise in next period although his expected wage rises. In equation (5.c), the realized value of the nominal wage in next period is given by the sum of the trend term, which is smaller than that of equation (6) and the diffusion term, which may take a negative value. The above proposition is tested empirically in Chapter III. See also Figure 3 in appendix 3.

[3] Anlysis of Quit Rates

This section analyzes on-the-job search process and quit behavior of a worker who maximizes the PDV of his lifetime wealth. The components of $A_{ij}(t)$ become important again here. The problem is to choose the optimal quitting time. The technique used in this section is the optimal stopping theory. In this section the term "wages" is used as the equivalent to "nominal wages". Most of the existing on-the-job search models with the reservation wage property assume either that a worker moves to a new firm which offers him a better initial wage than his current wage by assuming that workers have no information about the PDV (a myopic view), or that a worker compares the PDV of the new offer and his present job (a long-run view). This chapter takes the latter approach. Although a worker' real wage reflects the quality of the match, the match value does not exclusively determine job changes becuase of the existence of the rent-sharing agreement of OJT and the shifts in the DDL in the present chapter. Thus labor mobility is not necessarily productivity augumenting like a usual job matching model which assumes that a worker changes a job only when he finds a better quality of the match. The model assumes that workers are pure wealth maximizers.

A worker chooses the optimal quitting time by setting the reservation wage under the following assumptions.

(A1) The wage contract is perfectly flexible against the shocks in the product market and the possible randomness of the returns to OJT. The nominal wage of worker i at present firm j follows the stochastic differential equation (5.a) with the initial condition (5.b).

(A2) He can sample one job offer from a new firm with no on-the-job search cost in each time period. Therefore, he will search in each period. His employer cannot monitor his search activity and his outside wage offers.

(A3) The sampling of jobs is random. When he receives a new job offer, he can observe the current values of the product price, the real wage and the nominal wage. However, he cannot observe the value of the job perfectly.

(A4) He is not allowed to recall job offers that he rejected before. He also cannot return to his former job if he leaves.

(A5) The expected real productivity and the real wage at other firms are increased by OJT at the present firm although the rate of the return to that is lower than the present firm.

(A6) There are no layoffs.

(A7) There is no mobility cost.

(A8) The expected nominal wage growth rates take strictly positive values.

(A9) He does not search off the job; that is, he does not experience a spell of unemployment between the old job and a new job.

Furthermore, later, the model also assumes;

(A10) In next time period, some workers are sure to receive a better job offers from at least one firm whose job offer they rejected before and their expected wage growth rates at the firms are higher than their current firms. The wage of a typical job offer follows (11.a) with the initial wage offer (11.b).

Explanations about implications of the above assumptions are necessary. To consider involuntary permanent separations in the combined model of the HCI and the DDL is interesting. The DDL approach says that when product demand drops, a firm has an incentive to reduce the number of employees as well as the reduction of wages. However, this chapter focuses on the wage and the model assumes a perfectly flexible wage contract (see (A1)). Thus whenever the product price changes the wages of workers vary continuously, as in an auction market, to keep level of employment level constant. Moreover, it is well known that the firm-financed specific training negatively affects layoff rates (see Parsons (1972)). The model does not consider change in the level of employment (the hiring and layoff decisions of a firm) where the usual DDL approach considers (see Lucas and Prescott (1974)). In other words, the model makes a trick to allow the assumption of no layoff probability in equation (1.a) through equation (5.e). In the model, worker i's value marginal product (VMP), $p_j(t)\cdot q_{ij}(t)$, always exceeds his nominal wage, $p_j(t)\cdot x_{ij}(t)$ since returns of OJT are shared by worker i and firm j and the stochastic process of $q_{ij}(t)$ has the same error term as $x_{ij}(t)$. Suppose that an employer retains his workers as long as a worker's VMP is larger than his wage as in a usual HCI model, the employer never has a reason to fire a worker. At the same time, the employer has no incentive to provide an insurance against the negative shock in the product market (and a reduction of the wage) since each worker would move immediately to a new firm where the PDV is higher than the present firm because of (A2). In this model, firms encourage quits when product demand falls by lowing wages. Then, if workers find better outside opportunities, voluntary labor mobility occurs and the number of the employment will be reduced when firms' product demand drop. Thus there is no implicit contract which sustains the long-term employment. Instead there is an explicit contract about the wage paid and the costs and shares of OJT. A problem for an employer is how he could retain a valuable worker under a given wage contract. This point is discussed later. Although the assumption of no layoff probability is a weakness of this chapter, the present model has the advantage that it can consider quit rates. Actually, it is necessary to make careful arguments about layoffs in the combined model.[10]

(A8) is assumed in order to make the arguments simple. To assume (A9) is reasonable unless the expected outcome of the search depends on the method of search: either on-the-job or off-the-job. If there is no difference between two search method, no wealth-maximizing workers choose off-the-job search.[11]

Suppose worker i receives a job offer from firm 1 in period s from his search activity. Then the nominal wage, w_{i1}, follows an Ito stochastic differential equation:

$$dw_{i1} = A_{i1}(t)\ w_{i1}dt + B_{i1}(t)\ w_{i1}dz. \qquad (9.a)$$

with the initial nominal wage,

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10 For example, there are following four layoff decisions of an employer. First, he retains a worker as long as VMP is larger than the wage. (a typical assumption in a usual the HCI model) (see Hashimoto (1979)). Second, he retains a worker as long as the actual return to OJT or continuing a job matching is larger than the cost of them, which is typical in the job matching literature (see Antel (1985)). Third, a firm fires workers if they cheat and reduce their level of effort (however, we assume that workers keep providing their best effort as a usual the HCI model in this chapter). Fourth, a firm layoff a worker if it monitors that he receives a job offer from outside (see Ioannides and Pissarides (1982)). However, the case does not occur in this chapter because of (A2).

11 The most important reasons that a worker leaves the former firm before he finds a new job is that he expects a better search outcome; especially, he thinks the arrival rate of job offers is higher or the search cost is cheaper in the case of off-the-job search than on-the-job search.

$$w_{il}(s) = w_{ils}. \qquad (9.b)$$

where $A_{il}(t) = [a_l(t) + (\alpha_{il}\tau_{il}\emptyset(t)/x_{il}) + \delta_l(t)]$, $B_{il}(t) = [\delta_l(t) + 1]$ and s is the time period where worker i receives a job offer and starts a new job match with firm l. The derivation of the above equations and the meaning of the notation is exactly the same as equation (5.a) and (5.b). Equation (9.a) is interpreted as a stochastic nominal wage process where worker i works for firm l and invests in OJT at the firm. The expected nominal wage growth rate of firms, that is, $A_{ij}(t)$ in equation (5.a) and $A_{il}(t)$ in equation (9.a), become important factors in worker i deciding whether stay in firm j or switch to firm l (see Corollary 2 for the details).

How much does a worker's real productivity at other firms increase by OJT at his present firm? To consider this question, let β^j_{ik} ($\leq \tau_{ij}$) be the average rate of return to the investment in OJT at the present firm j in the real productivity at alternative firm k. Thus, $(\tau_{ij} - \beta^j_{ik})$ is a measure of realized specificity of human capital. See (A5). A stochastic real productivity process at firm k after worker i rejects its initial offer is, $dq_{ik} = \beta^j_{ik}\emptyset(t)dt + q_{ik}dz$. His real wage at prospective firm k, $x_{ik}(t)$, is an increasing function of OJT at his present firm j and increases by the rate, β^j_{ik}, although he continues working for firm j and has not yet moved to firm k. Note that (A5) also says that $\alpha_{ij}\tau_{ij} > \beta^j_{ik}$. The stochastic real wage process at firm k ($k \neq j$) in differential form is given as follows;

$$dx_{ik} = \beta^j_{ik}\emptyset(t)dt + x_{ik}dz \qquad (10.a)$$

with the initial real wage,

$$x_{ik}(s) = x_{iks} \qquad (10.b)$$

where s is the time period of the first job offer from firm k.[12] We can interpret $\beta^{j}_{ik}\emptyset(t)$ as an expected net increase in the real wage of worker i at firm k from OJT at his present firm j. Note that we do not multiply α_{ij} in (10.a) since firm k is not involved in OJT at firm j. Using the relationship, $w_{ik}(t) = p_k(t)x_{ik}(t)$, the nominal wage of worker i at the prospective firm k is

$$dw_{ik} = D(t)w_{ik}dt + B_{ik}(t)w_{ik}dz, \qquad (11.a)$$

with the initial nominal wage,

$$w_{ik}(s) = w_{iks}. \quad (11.b)$$

where $D(t) = [a_k(t) + (\beta^{j}_{ik}\emptyset(t)/x_{ik}) + \delta_k(t)]$. $B_{ik}(t) = [\delta_k(t) + 1]$, and w_{iks} is the initial wage offer from firm k to worker i. Thus, equations (13.a) and (13.b) show how the wage offer from firm k to worker i changes after worker i rejected the intial offer w_{iks} in time period s. $(\beta^{j}_{ik}\emptyset(t)/x_{ik})$ is the expected real wage growth rate

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12 Note that the real productivity and real wage of worker i at firm k increase by the same average rate of return, β^{j}_{ik}. However, the rate of return to OJT at firm j in the real productivity and the real wage at other firms is not usually equal to β^{j}_{ik}.

of worker i at firm k. D(t) decrease as the real wage of worker i at firm k. Note that D(t) is not a constant and it depends on time.

Let $V^l(t)$ be the PDV of an offer from firm l (a new firm; $l \neq j \neq k$) he receives by his job search activity in time perod t. Note that he receives one new job offer from a new firm in each period (see (A2)). Let $V^k(t)$ be the PDV of a new job offer from firm k which is the best available job offer for worker i in time period t among the firms whose job offer he rejected in the past. Two cases (case A and case B) are considered.

(case A): (A10) is not assumed. This case is similar to a usual on-the-job search model. The optimal quitting time of his present job, T^*, is the time such that

$$V^l(T^*) > V^j(T^*). \qquad (12)$$

Since the model assumes (A2), '(A4) and (A7), the above quit decision becomes optimal for worker i, which is supported by the optimal stopping theory without recall. He switches to a firm immediately if the PDV of the offer is higher than his present firm (see Lippman and McCall (1976) and Degroot (1970) for the formal optimal stopping theory). Here, the expected wage growth rates of jobs and the random sampling of job offers play important roles to determine the optimal quitting time. In this respect, the analysis is different from the existing models. The present model provides an interesting implications of the effect of situations of both the labor and the product markets on quit rates.

(case B): (A10) is assumed in addition to (A1) through (A9). (A10) provides an interesting analysis of the optimal quitting time. A usual optimal stopping rule without recall is valid under two assumptions; that is, a worker cannot recall rejected job offers and he cannot receive a new offer from the same firm whose job offers he rejected before because of a given wage distribution. (A10) and (A3) (the assumption of the random sampling) allow the latter case. Note that he cannot recall the past job offer of firms by (A4). Although the optimal stopping rule without recall and assumptions in this chapter ((A2), (A4) and (A7)) suggest that he will move to firm k if $V^k(t) > V^j(t)$ in period t (the time of its initial job offer), he may not switch to firm k if $w_{ik}(t) < w_{ij}(t)$ in (case B). This is because he wants to receive higher current wage as well as higher PDV than in his present firm in order to increase his lifetime wealth. Thus the usual argument of the optimal quitting time has to be modified if (A10) is assumed. The assumption that the wage of the firm he rejected before is not a constant after the rejection makes (A10) an interesting assumption. Remember that a rejected job offer becomes an increasing function of OJT at his present firm as well as the product price of the prospective firm. Since a worker with high productivity tends to receive replaced job offers, (A10) becomes more reasonable to assume the more human capital stock a worker has.

(A10) also plays an important role in answering the question whether a worker compares current wages or the PDVs when he makes a quit-or-stay decision. If a worker does not believe that the same firm gives him a new better offer in next period (without (A10)), then it is optimal for him to switch to a new firm if the PDV of the job is higher than his present firm. In the existing literature, an assumption of either a myopic or a long-run view is taken without any special explanation. This chapter analyzes when a worker with a long-run view also considers the current wage to make a quit-or-stay decision.

(1) Explanation of the Weakness of Usual HCI Models

Now consider the weakness of a usual HCI model by using equation (5.a), (5.b), (11.a) and (11.b). Note that usual HCI models assume that all workers have the same human capital initially and are different from our assumption of heterogeneity of workers. Here the quit behavior of a myopic worker is considered to make our analysis easier.[13] Assume that firm k is the best alternative prospective firm for worker i. Then worker i makes a quit-or-stay decision in any time period. He switches to firm k in period t if $w_{ik}(t) > w_{ij}(t)$.

Note, however, that $w_{ik}(t)$ can be decomposed into $p_k(t)$ and $x_{ik}(t)$. If product prices of all firms are the same in all time periods (as typical HCI models assume), a myopic worker actually compares the real wages, $x_{ij}(t)$ and $x_{ik}(t)$. Then, he switches to firm k when $x_{ik}(t) > x_{ij}(t)$. Suppose he knows that $x_{ik}(t) < x_{ij}(t)$

13 The argument here may be considered as a simple extension of a 2-period model of Hashimoto (1979). See Proposition 2 for the necessary condition of quitting and the explanation of the weakness of the HCI model in the case of a worker with a long-run view.

in period t where firm k gives worker i the best alternative job offer. Then it becomes difficult to explain job mobility from firm j to another firm since his quit-or-stay decision does not change in the future as long as the real wages, $x_{ij}(t)$ and $x_{ik}(t)$, change at the rates, $\alpha_{ij}\tau_{ij}\emptyset(t)$ and $\beta^{j}_{ik}\emptyset(t)$, respectively, resulting from OJT at firm j. One exception is the case of an unexpectedly high value of $x_{ik}(t)dz(t)$ relative to $x_{ij}(t)dz(t)$ which makes the real wage at firm k higher than firm j in next period. But an argument that relies only on high error terms as the cause of quits seems to be too weak. Even though it is assumed that the error term $x_{ik}(t)dz(t)$ includes some omitted variables which affect worker i's quit decision, the explanation of quits becomes easier if relative product prices are included explicitly in the argument. Then, if $p_k(t')$ (relative to $p_j(t')$) is large enough, the case $w_{ik}(t') > w_{ij}(t')$ will occur in period $t' > t$. This is an advantage of considering the DDL when a model is constructed under the HCI hypothesis. However, as worker i's job tenure at firm j increases, a gap between $x_{ij}(t')$ and $x_{ik}(t')$ becomes larger and the probability of quitting decreases.[14] A negative relationship between job tenure and quit rates is consistent with many empirical findings of job separation literature (see, for example, Mincer and Jovanovic (1981)) and an empirical finding in chapter V of this dissertation.

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14 If there is no firm-specific human capital, a worker switches to the firm with higher relative product demand.

(2) Explanation of the weakness of the merged model of the Job matching and the DDL approach

Next let us evaluate the combined model of the DDL and the job matching (JM) hypothesis (see Bull and Jovanovic (1988)). Here a myopic worker is assumed again. The basic idea of this approach is as follows. Define a nominal wage as a product of a fixed match value and a product price of his firm; that is, $w_{ij}(t) = p_j(t) \cdot q_{ij}$ instead of the original definition, $w_{ij}(t) = p_j(t) \cdot x_{ij}(t)$. This is also the same definition as in the model of Bull and Jovanovic (1988)[15].

Suppose myopic worker i at firm j has received a job offer from firm l in period t. He knows the values of $w_{ij}(t)$, $p_j(t)$, q_{ij}, $w_{il}(t)$, $p_l(t)$, q_{il} since the composition of the wage is revealed to the worker. A myopic worker is intersted in current wages and he switches to firm l if and only if $w_{il}(t) > w_{ij}(t)$. If $p_j(t) = p_l(t)$, he moves if $q_{il} > q_{ij}$. If this is the case, his quit decision is explained by the JM hypothesis (he moves to a firm which has a better match value). The typical assumption of the JM hypothesis is

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15 Technically, there are the following differences between their model and the present model. First, they assume a time invariant job match value. Second, they assume that prices across firms follow a Markov process with a steady state cumulative distribution without any rate (the present model assume an independent Markov diffusion process with a trend). Thus, they assume that a match value is a permanent component and a product price as a transitory component to the wage. In the present model both a match value and a product price are time variant and has an expected growth rate (trend) and a cyclical error terms. Here it is assumed that workers observe whether a firm is growing currently or not and whether or not it provides a good OJT.

that all firms face the same product price, normalized at unity; that is, the demand conditions are stationary. On the other hand, if it is assumed that all workers are homogeneous or he has the same quality of the match ($q_{ij} = q_{il}$), worker i switches to firm l if $p_l(t) > p_j(t)$. If this is the case, the DDL gives us an explanation of his quit decision. Thus, the combined model provides a clear analysis of quits in the case of a myopic worker. However, the model does not provide a good explanation for a worker with a long-run view since the PDV of each job offer depends only on a stochastic product price process, given a fixed match value. The present model is more powerful in analyzing the on-the-job wage growth and the quit behavior of a worker with a long-run view since each PDV depends on a stochastic process of the real productivity as well as a stochastic product price process.

(3) The Optimal Quitting Time

The optimal quitting time is analyzed under the above arguments. Remember that this chapter assumes that a worker knows an initial quality of the match and an initial PDV of a job immediately when he receive a new job offer. In this respect jobs are "pure inspection goods" or "pure search goods". However, note that the value of a job changes because of a stochastic nominal wage process (see (A3)). Define the present value of quitting as follows:

Definition 2: (The Present Value of Quitting)

The PDV of quitting in time period t, Q(t), takes two different values depending on whether (case A) or (case B) is considered.

$$Q(t) = \begin{cases} V^1(t) & \text{(case A)} \\ \max\{V^k(t),\ V^1(t)\} & \text{(case B)} \end{cases}$$

$$\text{where } V^k(t) = \int_t^{\infty} e^{(r-D(t))(s-t)} w_{ik}(t)ds, \quad (13)$$

$$\text{and } V^1(t) = \int_t^{\infty} \exp[(r-A_1(t))(s-t)]w_{i1}(t)ds. \quad (14)$$

Note that an individual worker has at least two options in (case B): a job offer from a new firm (see (A2)) in current period; and new (replaced) job offers from the firms whose job offers he rejected before.

The major difference between the present analysis and the existing voluntary turnover literature is that this model assumes that the nominal wage growth rate of both the present job and other potential jobs change depends on both the product market and the labor market (see Mortensen (1986) and Wright (1987) for the standard models). The optimal quitting time in (case B) is difficult to analyze. All we can say in general is that worker i of (case B) stays in firm j at least as long as in case A. This point is discussed more later. Case A is analyzed first.

(case A)

Under the above assumptions, worker i's problem is to maximize the PDV of his lifetime wage income by solving the following problem; that is, he maximizes the value of G(w,t) conditional on

$w_{ij}(t)$, which is given by

$$E\left[\int_t^{T^*} \exp[-(r-A_{ij}(t))(s-t)]w_{ij}(t)ds + e^{-r(T^*-t)}Q(T^*)\right] \quad (15)$$

where $Q(T^*)$ is the PDV of quitting at the optimal quitting time T^*. This is a modified version of (A8) in appendix of Jovanovic (1979a). Assuming an infinite horizon, the following equation holds at the optimal stopping time:

$$w_{ij}(t) = [r - A_{ij}(t)]Q \quad (16)$$

If $A_{ij}(t) = 0$, it boils down to the standard optimal stopping rule, $w_{ij}(t) = rQ$, where rQ is considered as "the imputed income" derived from the present value of quitting per unit time period (see Mortensen (1986)). Worker i stays in firm j if the following inequality holds:

$$w_{ij}(t) > [r - A_{ij}(t)]Q \quad (17)$$

Since the r.h.s of (17) is smaller than rQ, the imputed income from quitting becomes smaller than in the usual model. This means that the continuation region becomes larger than a usual case where A_{ij} = 0 and the worker tends to stay in his current firm longer. Implications of the model in (case A) are as follows. Firm-specific OJT reduces job turnover. Furthermore, as a firm's relative product demand rises, the firm can retain its existing workers and also attract outside workers. These are the same conclusion of a usual

HCI and the DDL approach, respectively.

Let $[\theta(t),t]$ be the boundary of the continuation region so that along the boundary $V^j[\theta(t),t] = Q$ holds, where $\theta(t)$ is the worker's minimum acceptance wage such that it is optimal to stay if $w_{ij}(t) \geq \theta(t)$ and quit if $w_{ij}(t) < \theta(t)$. It follows that

$$\theta(t) = Q[r - A_{ij}(t)] = V^j[\theta(t),t][r - A_{ij}(t)] \quad (18)$$

This is a modified version of the usual optimal stopping condition, $\theta(t) = rQ = rV^j[\theta(t),t]$. Since the r.h.s. of equation (18) is smaller than $rV^j[\theta(t),t]$, $\theta(t)$ also becomes smaller than in the usual case. Suppose worker i receives a job offer from firm l in period s, then $Q = (r - A_{il}(s))^{-1}w_{il}(s)$. Worker i stays in firm j if the following inequality holds:

$$\theta(s) > \frac{r - A_{ij}(s)}{r - A_{il}(s)} w_{il}(s) \quad (19)$$

Equation (19) says that as $A_{ij}(t)$ becomes larger the worker tends to stay longer in his present firm. In other words, as $A_{ij}(s)$ rises, the minimum acceptance wage $\theta(t)$ becomes smaller and the worker tends to stay longer in his current firm j.

The stay-or-quit decision is shown in the opposite way by defining the reservation wage of quitting as $\Phi(s)$; that is,

$$\Phi(s) = \frac{r - A_{il}(s)}{r - A_{ij}(s)} w_{ij}(s). \quad (19')$$

Worker i switches to firm 1 if $\Phi(s) > w_{i1}(s)$. This is a modified version of the standard optimal quitting condition, $\Phi(s) = rV^j(s) = rQ[\Phi(s)]$ (see Mortensen (1986)). As $A_{ij}(s)$ rises relative to $A_{i1}(s)$, the reservation wage to quit a job, $\Phi(s)$, increases. Then firm 1 needs either a higher initial wage offer or efforts to raise its expected wage growth rate, $A_{i1}(s)$, or both of them in order to induce a job separation of worker i from firm j.[16]

Note that the value of each job offer is represented by its initial nominal wage and its nominal wage growth rate in an infinite horizon case (i.e., $V^j(t) = V[A_{ij}(t), w_{ij}(t)]$). Thus worker i's reservation wage is higher (equal to, lower) than his current wage if $A_{ij}(s) > (=, <)\ A_{i1}(s)$. Thus in (case A) worker i with a long-run view takes current wages into his quit condition if and only if $A_{ij}(s) = A_{i1}(s)$. The above arguments say that any factors which make $A_{ij}(s)$ rise have a negative impact on quit decision of the worker.[17]

Remember that the firm has no layoff incentive in this chapter by (A1). However, a firm always faces a chance of losing its

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16 In this respect the present approach is related to the "overtaking" literature, which says that a worker with a constant wage switches to a new firm with a lower current wage and higher wage growth rate because of OJT there. Although the present model has the same taste, the implication is differenct since OJT occurs in all firms. In this model a worker's expected nominal wage growth rate of a new firm which reflects OJT and the product demand must be higher if its initial wage is lower than the worker's current job.

17 For example, if the worker changes the expectation of the future path of the product price of the current firm, or the firm becomes promising in its product market, it makes $a_j(s)$ rise and so $A_{ij}(s)$ goes up. Moreover, if $\emptyset(t)$ rises because of more OJT or firm j concedes and raise worker i's share of return to OJT, α_{ij}, then these factors make the value of $A_{ij}(s)$ increase.

employee whenever he finds a better outside opportunity. If a firm wants to retain a worker, the only way to do so is to raise the value of his job to discourage quitting. Given the quality of the present match, what is the easiest factor for firm j to affect the value of $A_{ij}(s)$ if it wants to retain worker i? Note that $a_j(s)$ is a difficult factor for firm j to affect because of competition in the product market with other firms, and it is not able to affect the cyclical deviation terms, $\delta_j(s)$. The best way for firm j to use is to increase the amount of investment in OJT, $\emptyset(t)$, by the firm-financed manner, or agree to raise the worker's share of return to OJT, α_{ij} (change the explicit contract favor to the worker). This argument is the same as the choice of the optimal share of returns to OJT in the existing firm-specific Human capital literature. (see Hashimoto (1979) and Antel (1985)). A firm does not have many options to retain its valuable workers in the present explicit contract although many factors will affect quit rates of workers. Other retention devices such as bonus payments (see Hashimoto (1979)) or promotion with a higher wage may be effective, but they are not consdired here. Furthermore, since a firm cannot monitor outside offers of a worker by (A2), it cannot give him a counter offer.

(case B):

Now consider quit behavior of worker i who can expect to receive new job offers from firm k whose former job offers he rejected. Consider the following two cases where there is no better alternative job offer such as $V^l(s) > V^k(s)$ in period $s \geq t$:

(1) worker i rejects a job offer from firm k in period t;

(2) he recives an offer from firm k such that $V^j(t) < V^k(t)$, but $w_{ij}(t) \geq w_{ik}(t)$.[18]

Then the interests of two cases are as follows, respectively:

(1) what is the required condition that he may accept the new offer from firm k in the future? - see proposition 2;

(2) whether or not he should accept the job offer in period t? If not when should he accept the job from firm k? - see proposition 3.

Case (1) is a general case. If a firm replaces a former job offer by an attractive offer, a worker may accept the new offer. A required condition for the case to occur is considered. Case (2) is a special case of (case B) where worker i in (case A) accepts the offer from firm k. In this case this chapter shows his optimal quitting time is determined and discusses the differences between a standard on-the-job search model and (case B). If a worker believes he will receive a better offer (with the higher initial wage) in the next period, he will wait to move to the new firm and reject the current offer even though the PDV of the new offer is higher than in his present firm. As an alternative explanation of why a worker with a long-run view also consider the current wage in his quitting decision is as follows. If a worker is looking for a new job in an expanding industry

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18 Note that if the initial wage from the new firm as well as the PDV is higher than his current firm, to consider (2) is not interesting and does not affect his optimal quitting decision; that is, he switches to the new firm when he receive the first job offer.

(or occupation) he has more chances to receive better job offers in the future than job search process in declining industry. In this case, firm k is considered as a typical firm in the growing industry where any firms in the industry want to raise the employment level and are willing to provide good job offers. If the situation is good enough to make him believe that a better offer comes in the next period, then he will conclude that the current time where the PDV of the offer is higher but the current wage is lower than his present firm is not the optimal quitting time. If this is the case he tends to care about the current wage as well as the PDVs of job offers.

First, as the answer for case (1), the following proposition is derived:

Proposition 2:

Suppose worker i in (case B) rejects a job offer from firm k in period t, and there is no better alternative job offer than firm k in both current and next period. Then the necessary condition for a worker to switch to firm k in the next period is that the realized amount of the increase in firm k's relative product price is larger than that of firm j's.

Proof: It is obvious that the required condition for worker i to move to firm k in the next period is $D(t) > A_{ij}(t)$ when $V^j(t) > V^k(t)$. That is,

$$[a_k(t) + (\beta^j_{ik}\emptyset(t)/x_{ik}(t)) + \delta_k(t)] > [a_j(t) + (\alpha_{ij}\tau_{ij}\emptyset(t)/x_{ij}(t)) + \delta_j(t)]. \qquad (20)$$

The condition (20) is simplified as follows:

$$[a_k(t) + \delta_k(t)] - [a_j(t) + \delta_j(t)]$$
$$> [\alpha_{ij}\tau_{ij}\emptyset(t)/x_{ij}(t)] - [\beta^{j}_{ik}\emptyset(t)/x_{ik}(t)] \qquad (21),$$

which implies that the difference between the sum of the expected growth rate and the standard error of firm k's relative product price and the sum of those values for firm j is larger than the difference between the expected real wage growth rate of the two firms. By using Figure 3 in appendix 3, the value of $[a_k(t) + \delta_k(t)]$ determines the realized value of the product price in the next period.[19] Then (21) says that the actual amount of an increase in the relative product price between two periods must be higher in firm k than firm j, which is the same as the statement of Proposition 2. Q.E.D.

Note that (21) is not a sufficient condition at all. Note also that since both product prices and real wages follow stochastic processes. The above proposition explains the importance of the effect of shifts in derived demand relative to the effects of the firm-specific OJT as a determinant of a worker's quit decision. It says that sum of the growth rate and the standard error of the new firm's relative product price must be large enough to make up the

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19 The terms, $A(m)w_{ij}(m)$ and $B(m)w_{ij}(m)$, have to be changed to $a_k(t)p_k(t)$ and $\delta_k(t)p_k(t)$, respectively. Remember that a diffusion term, $\delta_k(t)p_k(t)\_z(t)$, can take either a positive or a negative value since $z(t)$ is a standard Wiener process.

disadvantage of the lower rate of return to the investment in OJT at the present firm of the worker; that is, $\alpha_{ij}\tau_{ij} > \beta^{j}_{ik}$ by (A5).[20] Thus the decision to quit and accept a previously rejected offer is explained by the DDL approach as long as realized specificity of human capital exists.

As an informal explanation of the weakness of a usual HCI model in the case of a worker with a long-run view (see section [1] for the case of a myopic worker). Proposition 2 can be interpreted as follows. Suppose t is the first period of labor force participation for worker i. Assume that $x_{ij}(t) = x_{ik}(t)$ like a usual HCI model (the same initial stock of human capital) where firm k is one of any other firms. Note that it is not necessary to assume (A10) in the following argument. Suppose worker i starts to work at firm j. If the DDL hypothesis is not considered, worker i's quit decision cannot be explained by a usual HCI model since $\alpha_{ij}\tau_{ij}/x_{ij}(t) > \beta^{j}_{ik}/x_{ik}(t)$ (note $x_{ij}(t) = x_{ik}(t)$). That is, if the case is $[a_j(t) + \delta_j(t)] = [a_k(t) + \delta_k(t)]$, or $a_j(t) = a_k(t) = \delta_j(t) = \delta_k(t) = 0$, then the case $A_{ij}(t) < D(t)$ never occurs. Thus worker i with a long-run view (as well as a myopic worker) never leaves firm j as long as firm-specific OJT is provided in firm j. However, if the DDL hypothesis is combined and $[a_k(t) + \delta_k(t)]$ is large enough relative to $[a_j(t) + \delta_j(t)]$, then the case $A_{ij}(t) < D(t)$ will occur, and the necessary condition of quitting in next period is given by (21).

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20 Suppose that the difference between the real wages, $x_{ij}(t)$ and $x_{ik}(t)$, is large enough, the case where $[\alpha_{ij}\tau_{ij}\emptyset(s)/x_{ij}(s)] < [\beta^{j}_{ik}\emptyset(s)/x_{ik}(s)]$ may occur. However the necessary condition of quitting in the future is still given by (21).

Thus, an appropriate analysis of a voluntary job separation cannot be provided unless the derived demand shifts are taken into the consideration explicitly in a usual HCI model.

How about the case (2)? Remember that the interest here is in the case where worker i chooses the optimal quitting time, t^*, given that $V^k(T^*) > V^j(T^*)$ and (A10). Note T^* is the optimal quitting time in (case A) and $t^* \geq T^*$; that is, he tends to stay longer in the present firm in case (2) of (case B) than (case A) since he expects better job offers to come from firm k in the next period. Thus, the same optimal quitting condition as (case A) cannot be applied (see inequality (19) and equation (19')). In (case B) the analysis becomes very complicated unless a special assumption is made.

Figure 1 is helpful to understand the difference between (case A) and case (2) of (case B). He receives a job offer in period T^* from firm k with the initial wage, $w_{ik}(T^*)$ (point D), which is lower than his current wage, $w_{ij}(T^*)$ (point C located higher than point D). It is assumed that he does not receive a better job offer than firm k after T^*. By (A3) worker i knows that total wage income in his remaining life at firm k is larger than firm j. If he actually switches to firm k in period T^* (worker i in case A), his wage at firm k increases by the expected nominal wage growth rate, $A_{ik}(T^*) = [a_k(T^*) + (\alpha_{ik}\tau_{ik}\emptyset(T^*)/x_{ik}) + \delta_k(T^*)]$. His lifetime wage path becomes BCDFHI in Figure 1. In the figure, the wage at firm k becomes larger than firm j after time period T_1 (point H). If he rejects the job offer in T^*, the wage offers from firm k increase by the rate, $D(T^*)$, after T^* until he switches to firm k in the optimal quitting time, t^*. Although worker i of (case B) receives a higher wage than worker i of (case A) until T_2, his initial wage at firm k, $w_{ik}(t^*)$ (point E), becomes lower than the wage he receives if he switches in T^* (point F) since $A_{ik}(T^*) > D(T^*)$. If he waits to switch to firm k until T_2 when a new wage offer from firm k becomes larger than his current wage (point L), he receives more wage income than (case A) by the amount of CDH, but his forgone wage income will be HIML. If the forgone income (HIML) is larger than his extra earning (CDH), then he quits before T_2 (since $w_{ij}(t) < w_{ik}(t)$ after T_2, the optimal quitting time of worker i of case B, t^*, is between T^* and T_2). In Figure 1, t^* is located between T^* and T_1. His lifetime wage path becomes BCGEKJ. In this case, he receives more earnings than (case A) by the amount of CDFG, but, on the other hand, he receives less earnings after t^* by the amount of EFIJ than (case A). Thus, the optimal quitting time is the time when a difference between the area of CDFG and EFIJK is maximized since this is the time to maximize his expected lifetime wealth.

Since the analysis in case (2) is usually very complicated, the following special assumption is made in order to make the argument easier and derive some intersting iimplications about the optimal quitting time:

(A11) For some workers, the wage growth rates at prospective firms are the same whether they stay and invest in OJT at their present firms or they switch to the prospective firms and invest in OJT there.

If (A11) is assumed, the wage path after T^* becomes the same whether a typical worker (worker i) swithches to firm k or he stays in firm j and invests in OJT there. In other words, (A11) means $A_{ik}(T^*) = D(T^*)$. This is the same as assuming $\alpha_{ik}\tau_{ik} = \beta^j_{ik}$. That is, the average rate of return to investment in OJT at firm j at firm k is the same as the expected average rate of return to direct OJT at firm k.[21]

Figure 2 illustrates this case. In this figure, a worker of (case B) receives more wage income in his lifetime than (case A) by the area of BCH given that he does not receive better alternative job offers from after T^*. His lifetime wage path becomes ABHI.[22] The following proposition is derived in (case B) with (A11):

<u>Proposition 3</u>:

Suppose worker i at firm j in (case B) with (A11) samples a new job offer from firm k in each period where there is no better alternative job offer than firm k in the meantime. Then, he compares a job offer from firm k with his present job and he never accept a new job offer from firm k until the following two conditions are satisfied:

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[21] Note $A_{ik} = [a_k(t) + (\alpha_{ik}\tau_{ik}/x_{ik}) + \delta_k]$ and $D(t) = [a_k(t) + (\beta^j_{ik}/x_{ik}) + \delta_k(t)]$.

[22] Although the expected nominal wage growth rate may change during a job tenure, worker i assumes the wages increase by the rates, $A_{ij}(t^*)$ and $D(t^*)$, respectively during each time period through his retirement age. He makes a quit decision by assuming that a firm with a higher current expected wage growth rate has a higher rate in the future than a firm with a lower current rate.

$$w_{ik}(t^*) \geq w_{ij}(t^*); \qquad (22.a)$$

$$V^k(t^*) \geq V^j(t^*); \qquad (22.b)$$

where one of the inequalities must hold as a strict inequality.

Condition (a) says that the reservation wage is $w_{ij}(t^*)$ for a worker in (case B) with (A11). Condition (b) says that the wage growth rate at firm k must be higher than firm j; that is, $A_{ik}(t^*) = D(t^*) > A_{ij}(t^*)$ when condition (a) is satisfied with the equality. It follows a corollary immediately.

<u>Corollary 1</u>:

Worker i in (case B) with (A11) makes the following stay-or-quit decision in period t:

1) when $w_{ij}(t) \geq w_{ik}(t)$ and $V^j(t) \geq V^k(t)$, worker i stays in his current firm j;
2) when $w_{ij}(t) > w_{ik}(t)$ and $V^j(t) < V^k(t)$, worker i rejects the replaced job offer from firm k, but may accept a new job offer from firm k in period t' (> t) when $w_{ij}(t') \geq w_{ik}(t')$;
3) when $w_{ij}(t) \leq w_{ik}(t)$ and $V^j(t) \geq V^k(t)$, he stays in firm j;
4) when $w_{ij}(t) \leq w_{ik}(t)$ and $V^j(t) < V^k(t)$, he switches to firm k in period t.

Note that worker i in (case A) would switch to firm k in case 2) above since worker i in (case A) switches to firm k immediately if $V^j(t) < V^k(t)$ regardless of the initial wage offer. Now consider a required condition that worker i switches to firm k in period t, given that condition (22.a) is satisfied with equality. Looking at case 4) of Corollary 1, the following corollary is derived:

<u>Corollary 2</u>:

Suppose worker i receives a new job offer from firm k which pays him the same nominal wage as firm j. If the expected real wage growth rate of worker i at firm k is lower than firm j, then firm k has to be more promising in the product market to attract worker i and induce him to quit.

Proof: From the assumption (A11), $\beta^j_{ik} = \alpha_{ik}\tau_{ik}$. By Proposition 3 when $w_{ij}(t) = w_{ik}(t)$, worker i quits if $V^k(t) > V^k(t)$. In an infinite horizon this implies that $D(t) > A_{ij}(t)$ is a necessary and sufficient condition for worker i to quit. That is,

$$[a_k(t) + (\alpha_{ik}\tau_{ik}\emptyset(t)/x_{ik}) + \delta_k(t)]$$
$$> [a_j(t) + (\alpha_{ij}\tau_{ij}\emptyset(t)/x_{ij}) + \delta_j(t)], \text{ or}$$

$$[a_k(t) + \delta_k(t)] - [a_j(t) + \delta_j(t)] >$$
$$[\alpha_{ij}\tau_{ij}\emptyset(t)/x_{ij}] - [\alpha_{ik}\tau_{ij}\emptyset(t)/x_{ik}], \qquad (23)$$

which is the same as the statement of corollary 2. Q.E.D.

Note that this is a necessary and sufficient condition to quit in case (2) (compare with Proposition 2 in case (1) of (case B)). Corollary 2 is applied to quit decisions of a worker with a long-run view in (case A) when the current real and nominal wages of the two firms are the same. That is, this is exactly the same required condition to make worker i at firm j leave for firm l when $w_{ij}(t) = w_{il}(t)$ (see equation (9.a) and (9.b)). Remember that worker i in (case A) switches to firm l in period t if $A_{il}(t) > A_{ij}(t)$ when $w_{il}(t) = w_{il}(t)$. Corollary 2 provides an implication about the relationship between the derived demand shifts and the OJT programs of firms. A firm has to provide a more efficient training program or gurantee a higher worker's share of return to OJT if the firm is expanding less in the product market than the worker's present firm when both the real and the nominal wages of two firms are the same.

Whether $w_{ik}(t) \geq w_{ij}(t)$ in addition to the condition $V^k(t) > V^j(t)$ is a necessary condition of quitting or not is an interesting empirical question since w_{ij} is not usually the same as his reservation wage (see (case A) of this chapter). If a worker switches to a new firm only when $w_{ik}(t) > w_{ij}(t)$, it becomes a contradiction against the standard theoretical argument.[23] Then it suggests that it is necessary to modify a standard on-the-job search model and to develop an alternative theoretical argument like case (2) of (case B) in the present chapter.

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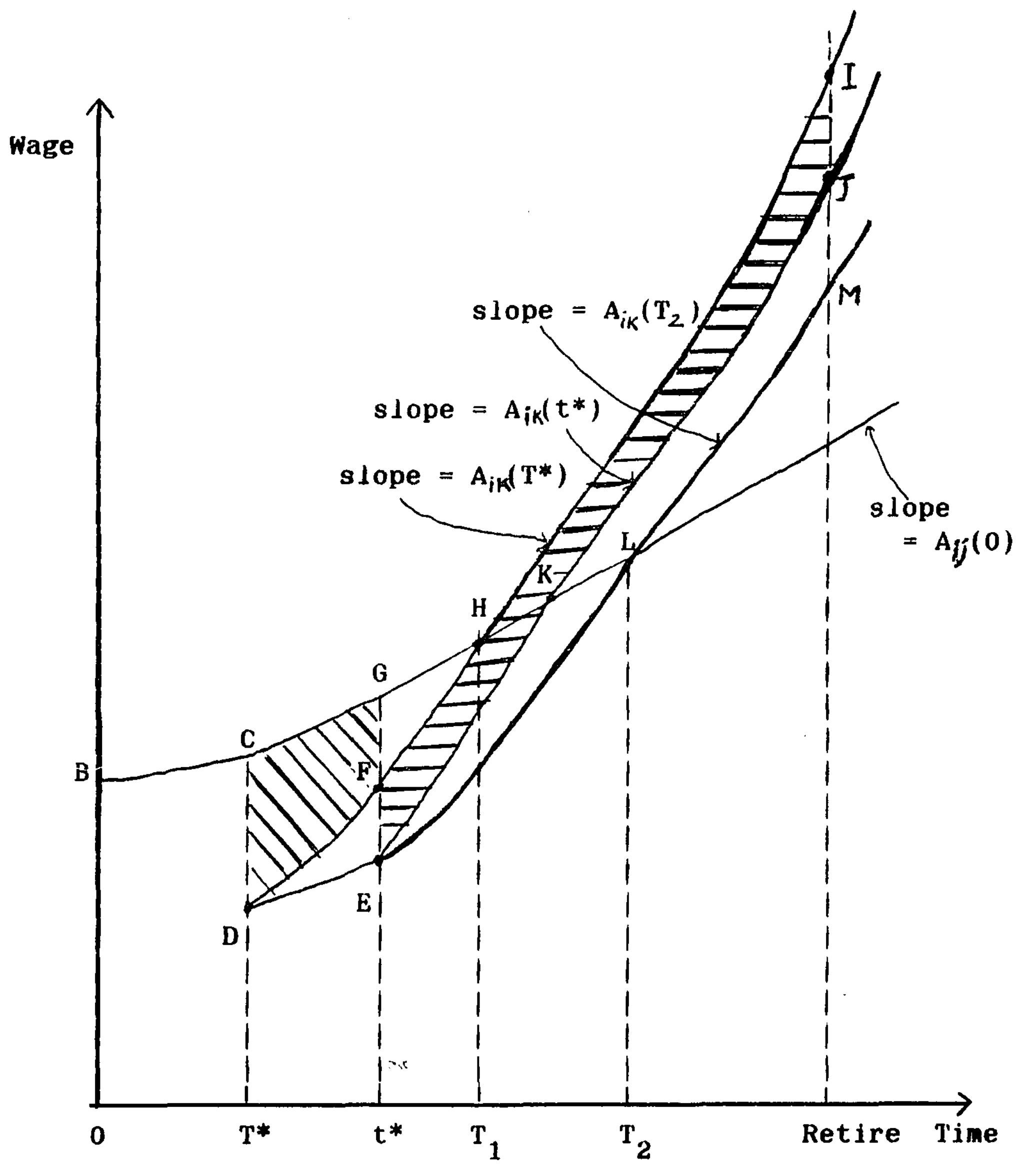
23 Gottschalk and Maloney (1985) reports that 41 percent of people who reported that they were better off had lower real wage rates than in their previous job between 1978 and 1979 interview year of Panel Study of Income Dynamics.

[4] Conclusions

This chapter shows that the power of a human capital investment model in explaining a worker's quit behavior as well as wage changes increases if it is merged with the derived demand for labor approach. It derives a stochastic nominal wage process which reflects the effects of both the product and the labor market. Then this chapter analyzes a quit decision of a worker who maximizes the PDV of his lifetime wealth under uncertainty. The model especially considers whether a worker also compares the current wages when he makes a quit-or-stay decision. This chapter provides many empirical implications which are testable.

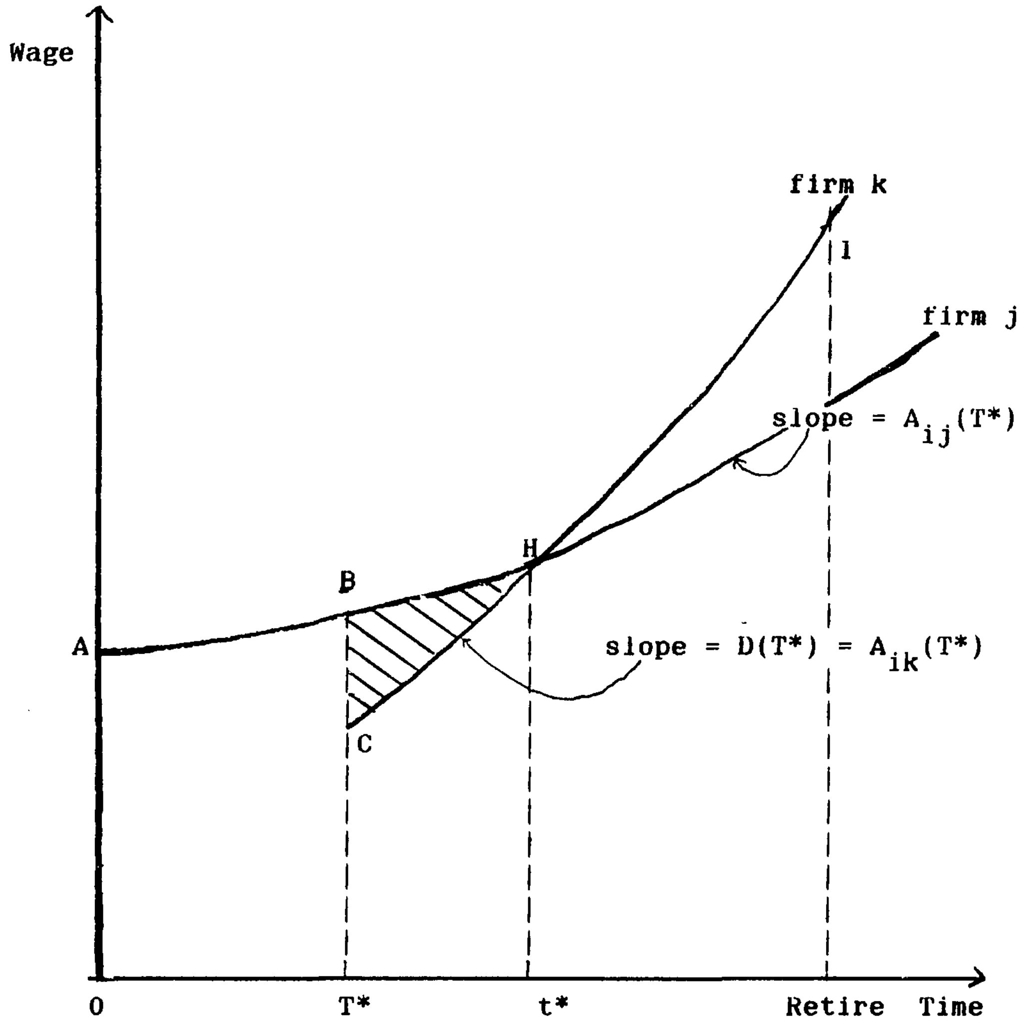
Whenever a worker receives a new wage offer, he calculates the PDV of the offer from its stochastic wage process. He makes two different quit decisions depending on his belief. If he does not believe that any firm will give him a new better offer, it becomes similar to a standard on-the-job search model. He moves to a new firm immediately if the PDV of a job offer from a new firm is better than his present job when there are no search costs and no mobility costs. If he believes that at least one firm will give him a new better offer in next period, he may not switch to a new firm immediately even if its PDV is higher than his present job. If he knows that the wage growth rate of a prospective firm is the same whether he stays and invests in OJT or switches to the firm and invest in OJT there, then he switches to the firm if and only if both the cuurent wage and the PDV of the job offer are better than his present firm.

Figure 1



Wage
I
J
M
slope = $A_{iK}(T_2)$
slope = $A_{iK}(t^*)$
slope = $A_{iK}(T^*)$
slope
= $A_{ij}(0)$
L
K
H
G
C
B
F
E
D
0
T*
t*
T_1
T_2
Retire
Time

Figure 2


Wage
firm k
1
firm j
slope = $A_{ij}(T^*)$
H
B
A
slope = $D(T^*) = A_{ik}(T^*)$
C
0
T*
t*
Retire
Time

CHAPTER III

Estimation of an Earnings Function

[1] INTRODUCTION

This is the first chapter to provide empirical support for the theoretical model in chapter II. The purpose of this chapter is to show the existence of wage differentials among individual workers due to the effect of shifts and shocks in product demand in their firms (industries). That is, this chapter merges the DDL approach with the HCI approach and estimates an earnings function using micro-data. The empirical finding of this chapter shows that the DDL approach adds considerably to the traditional HCI approach explaining wage changes of individual workers. It reports that a worker is paid more as the industry product demand becomes higher and more cyclical.

The main objective of the present chapter is to estimate the effect of product demand on the wages of individual workers. The chapter shows the importance of the variables on the demand side of the labor market derived from the product market in addition to human capital variables in estimating an earnings function. The statistical technique underlying the estimates is a variance components model. The Panel Study of Income Dynamics (PSID) is used to obtain a sample of male household heads and merged with published data on industry prices and other demand variables pertaining to the industry and county in which the respondent works.

The most difficult problem of this approach is the choice of appropriate proxies for firms' product prices since they are not usually obtainable for individual workers in panel data. An earnings function is estimated by a two-step procedure. Consumer and producer price indices for industries are used as proxies for firms' product price and a trend and a cyclical deviation for each industry-specific product demand are calculated by time-series regressions. Second, those variables are included on r.h.s. of an earnings function as independent variables. In addition, published data on other demand variables are added and their effects on an earnings are estimated. Since the demand variables are merged with panel data, these approaches are related to Adams (1985).[24]

This chapter is organized as follows. Section 2 is the main section. First, it explains how the effects of product demand are estimated within an ordinal estimation of an earnings function in order to show why the approach in this chapter is interesting. Then it explains the two-step estimation procedure which merges proxies

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24 The main objective of his work is to test whether there exist wage premiums which come from geographic and industry unemployment differences. He uses the value added of each industry and GNP, and calculates relative growth of and the cyclical sensitivity of industry output by a slightly different way from this chapter. Then he includes these variables on the r.h.s of an earnings function as well as human capital variables and other demand side variables (state unemployment rate, current industry unemployment rate, state replacement ratio, and durable and nondurable manufacturing dummies). He found that current industry unemployment affects the wage negatively and that the state unemployment induces a wage premium. The most important contribution of his chapter is the effect of the unemployment insurance (UI) on wages. After calculating the UI replacement ratio of each state carefully, he found that an increase in UI benefits induces a wage cut.

variables for firms' product price with the PSID. Results of cross-sectional regressions and Pooled GLS results are shown. Those results establish that the effects of shifts and shocks in industry-specific product demand are significant, especially for young workers. Section 3 presents some concluding remarks.

[2] Identification and Estimation

This section presents an estimation technique for the earnings function that was derived in chapter II and shows empirical findings. Proposition 1 in chapter II is tested empirically. Note that the present chapter does not try to reject the traditional HCI approach in estimating an earning function. Instead, the main objective here is to show the importance of the demand variables as well as human capital variables in the estimation.

At the empirical level, there are the following problems that make the estimation of the effects of product demand on an earnings function difficult: 1) whether product prices of firms are identifiable or not; 2) given that firms' product prices are not obtainable, what are appropriate proxy variables for firms' product prices? There are two econometric techniques that can take product demand into consideration. The first approach is to take the product price as unobservable, include it as one of the composition of the error term, and discuss a possible correlation between independent variables and the error term. Altonji and Shakotko (1987), and Bull and Jovanovic (1988) adopted this approach. The second approach is to use appropriate proxy variables for the product prices and merge those variables with panel data. Adams (1985) takes this approach. This chapter adopts the latter strategy.

The Panel Study of Income Dynamics (PSID) is used to obtain a sample of prime aged male household heads who were observed between the 1978 and 1984 interview years. To be included in the sample the head had to be employed at the date of interview, and not self-employed in all years. Two male samples are used; a sample of all races and a sample limited to whites. In the second approach PSID is merged with published data on industry prices and other demand variables pertaining to the industry and county in which the respondent works (i.e., producer and consumer price index, employment rate of industries, and the unemployment rate of a worker's industry and county as proxies for product prices of firms). The statistical technique underlying the estimates is a variance components model. It is assumed that an error term is composed of individual, time, and random error components. In order to make clear the difference between the first and second approach and to show two reasons why the present chapter uses the second approach, the first approach is explained.

(1) First Approach

Consider the following log wage equation:

$$\ln w_{ijt} = X'_{ijt}\beta_1 + \beta_2 TN_{ijt} + \beta_3 TN^2_{ijt} + u_1, \quad (24.a)$$

$$u_1 = p_{jt} + f_i + d_t + v_{ijt}. \quad (24.b)$$

where ln w_{ijt} is the natural log of the hourly wage rate of worker i at firm j in interview year t ((total labor income in year t-1)/(total hours of work in year t-1)) deflated by the average consumer price index in period t-1. Individuals whose hourly nominal wage is less than two dollars or more than fifty dollars are deleted in any interview year. The error term, u_1 consists of a time-varing effect of firm j's relative product price p_{jt}, a fixed individual effect f_i, time specific effect d_t, and a transitory iid error component v_{ijt}.[25]

X_{ijt} is a K x 1 vector of observable individual worker-specific, time-varying productivity characteristics, including human capital variables except job tenure. Precise definitions of variables in x_{ijt} are as follows:

1) the number of years of schooling completed as of each interview date;
2) the number of years of full-time labor force experience;
3) the square value of the number of years of labor force experience;

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25 In order to focus on the effect of firm's product demand on the earnings, the present chapter neglects a job match effect in the error component although it is also important to include it when panel data are used. If the match component is included in the error term, a possible negative correlation between the tenure variables and the error component has to be considered. In this case, special technique such as instrumental variables estimator or a GLS regression should be applied since the OLS estimator on the tenure variables are biased. Altonji and Shakotko (1987) provide detailed explanations on this point, and this chapter omits them.

4) a dummy variable for union coverage (whether or not the job is covered by collective bargaining);

5) a dummy variable for marital status (whether married or not);

6) a dummy variable for durable manufacturing industries;

7) a dummy variable for nondurable manufacturing industries;

8) a dummy variable for race (whether white or not).

Industry dummies are included in all regressions to control for relevant industry characteristics. TN_{ijt} is job tenure in years of worker i at firm j in period t, and is coded, for example, two if the worker has been with firm j at least 24 months but not yet 36 months. Thus, if worker i has not been working for a firm for at least one year (i.e., if he has changed a job between two interview dates) $TN_{ijt} = 0$. β_1 is a K x 1 parameter vector to be estimated.

Assume that p_{jt} follows a AR(1) process such that, $p_{j,t+1} = \theta_{jt}p_{jt} + \Phi_{jt}$ (this notation is slightly different from equation (1.c)). As Bull and Jovanovic (1988) mention, a problem in error component is that p_{jt} is distingushable from v_{ijt} only when $\theta_{jt} = 0$ or 1 because it is the same for all workers in the same firm. Furthermore, even though p_{jt} is distinguishable from v_{ijt} theoretically, the contribution of p_{jt} cannot be identified at the empirical level with panel data such as the PSID that do not include several workers from each firm. This is the first reason that the present chapter uses proxy variables for firms' product prices and excludes p_{jt} from the error component when estimating the earnings function derived in section II.

A second reason to use proxies for firms' product prices is shown as follows. When θ_{jt} is not equal to zero or one (p_{jt} is serially correlated), a possible correlation between TN_{ijt} and v_{ijt} (actually, because of p_{jt}) has to be considered since it induces a bias in OLS estimates of the wage-tenure profile.[26] The following argument is similar to Altonji and Shakotko (1987) since p_{jt} here is close to the transitory job match component in that chapter. A decline in p_{jt} in the error component raises the relative value of worker i's outside job offers, and thus increases the probability of worker i quitting to go to an alternative job. If p_{jt} is serially uncorrelated ($\theta_{jt} = 0$), it will be weakly correlated with TN_{ijt}, because TN_{ijt} depends on past quit and layoff decisions, and a wage disturbance which lasts only a single period should have little effect on quit decisions. However, if p_{jt} is serially correlated (for example, an AR(1) process), there is a significant correlation between TN_{ijt} and p_{jt}. Since this chapter assumes the specificity of human capital by investment in OJT, the gap in real wage between firm j and other firms increases as long as a worker continues to invest in OJT at firm j. This implies that quit probability is a declining function of job tenure. In other words, the amount of the decline in p_{jt} necessary to induce a quit is an increasing function of the job tenure. Thus, the expected value of p_{jt} conditional on the continuation of the current job declines with TN_{ijt}. Conditional on no quit probability (probably because of a large amount of specific human capital obtained through OJT), TN_{ijt} is negatively correlated with the conditional expectation of p_{jt}. Thus, OLS estimates of the wage-tenure profile will be downward biased. By a similar argument, selection due to layoffs will produce an upward bias on the OLS estimates of TN_{ijt}, and so the two effects will partially offset. However, if a perfectly flexible wage contract against the changes in the firm's product demand results in no layoffs, only the the downward bias is necessary to consider.

Assuming that there is no serious sample selection problem, one way to cure the downward bias is to use an instrumental variable for tenure. However, instead of taking this approach with p_{jt} in the error component, the present chapter uses proxies for p_{jt} and includes them as independent variables on r.h.s. of an earnings function. Then unbiased estimates of the wage-tenure profile can be obtained so long as the proxies are appropriate and there is no other correlation between tenure and the error component. If there are no significant unobserved job-match effects, the approach of this chapter should provide unbiased estimates.

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26 Bull and Jovanovic (1988) developes a merged model of the DDL and the job matching hypothsis and treat both the match value and the product price as unobservable variables in the estimation. In their model the error term has three components; the time-invariant match specific component, a AR(1) product price component and i.i.d. random error term. They say, "the total error term will exhibit negative correlation, if ignored, will lead to a downward bias in the tenure coefficient. This may be why Abraham and Farber (1986) and Altonji and Shakotko (1987) report surprisingly low estimates for this coefficient." In other words, even though, the job match effects are considered and cured, if the effects of shifts and shocks in product demand are neglected, the estimates of the wage-tenure profile are still biased. The present chapter attempts to cure this bias by using proxy variables (treat product prices as observable variables) although it neglects a possible bias by the job match effect for its objective.

(2) Second Approach

The first step in this approach is to choose an appropriate proxy variable for firm j's product price, p_{jt}. The present approch uses producer price indices for manufacturing and consumer price index for other industries as proxy variables for firms' product prices. It considers two samples of male household heads by using 2-digit and 3-digit industry classifications, respectively. For the former case, the sample from the 1978 to the 1984 interview year is used and workers are classified into 15 industries. For the latter, the sample from 1981 to 1984 is used since the data for 3-digit industry classifications are not presented in the PSID before 1981. In this case workers are classified into 25 industries and manufacturing and service industries are classified in finer sectors.[27]

In order to find the appropriate matching of a price index and an industry, there is a restiction on the number of industries included in two samples. About sixty percent of workers in the samples are in manufacturing. The two samples include the workers in the manufacturing, transportation, public utility, service industries. In other words, they exclude workers in agriculture,

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27 Although a finer classification of industries is possible, this chapter does not do that since the data of unemployment and employment are not available for the finer classification. Note that the 3-digit industry classification can be easily translated into 2-digit classification. Thus we can combine the sample of data from the 1981 to the 1984 interview year which have only 3-digit indusry classifications with the sample of data from 1978 to 1980. In the sample of 2-digit classifications, It follows the industry classifications of the PSID.

mining, construction, retail and wholesale trade, finance, and insurance. The appendix 5 contains the industries included in each sample.

The estimation of the earnings function follows a two-step procedure. First, equation (1.a) in chapter II is estimated using either the consumer or producer price index pertaining to the industry. A trend and a deviation of the relative product price for each industry are caluculated from a time-series regression based on the most recent fifteen years of evidence. For example, in the case of earnings in 1980, price indices from 1966 to 1980 for each industry are used. For the earnings in 1981, the price indices from 1967 to 1981 are used, and so on. The regression runs $\ln(p_{jt}/CPI_t)$ on a time trend, where p_{jt} is producer (or consumer) price index of industry j (worker i's industry) and CPI_t is the average consumer price index in year t.[28] That is,

$$\ln (p_{jt}/CPI_t) = \Phi_{jt} + a_{jt}(TIME) + e_{jt}. \qquad (25.a)$$

Predicted values, a_{jt}, are trend amounts of log of relative industry product price, while residual values, σ_{jt} (standard error of esimate), are cyclical deviations from trend, and Φ_{jt} is the constant term. Note that these values are both time and industry specific. Seven different regressions are run in 15 industries when

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28 Both producer and consumer price indices are available from U.S. Department of Labor, Bureau of Labor Statistics. All price indices set the 1967 value equal to 100.

the sample of 1978-1984 interview years is used. Time index starts in 1962 and ends in 1983.

There is one problem for this procedure because the estimates in equation (25.a) may also pick up the effect of macro business cycle. Note that our interest in this chapter is to find the effect of shifts and cyclical shocks in industry-specific product demand on the earnings of workers. To eliminate the effect of business cycle, men's national unemployment rate of twenty-years-old and over is included in the relative price regressions in each year.[29] That is, the equation to be estimated is

$$\ln\,(p_{jt}/CPI_t) = \Phi^*_{jt} + a^*_{jt}(TIME) + b_{jt}(UNEMPLOYMENT) + e^*_{jt}. \quad (25.b)$$

Then, a^*_{jt} becomes the correct trend amounts of log of relative industry product demand, and σ^*_{jt} are true cyclical deviations from trend. Second, the variables, a^*_{jt}, b_{jt}, and σ^*_{jt} are included on r.h.s. of an earnings function as independent variables as well as typical human capital variables.

Thus, the earnings function estimated by cross sectional regressions is

$$\ln w_{ijt} = X'_{ijt}\beta_1 + \beta_2 TN_{ijt} + \beta_3 TN^2_{ijt} + \alpha_1 a^*_{jt} + \alpha_2 \sigma^*_{jt} + \alpha_3 b_{jt} + u_2 \quad (26)$$

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29 U.S. Department of Labor, Bureau of Labor Statistics is the source of the data.

where u_2 is i.i.d. error component here. Note that the coefficients on UNEMPLOYMENT in (25.b) should be included in order to eliminate business cycle effects on the earnings.[30] Table 1 shows mean values of primary demand variables in the sample between 1981 and 1984. Results of cross-sectional regressions for 3-digit industries classifications are shown in Table 2.a (all races) and Table 2.b (white).

Note that every white male sample causes smaller coefficients on a^*_{jt} and σ^*_{jt}. This suggests that white workers are less vulnerable to shifts and shocks in product demand.

The earnings function to be estimated by pooled GLS regressiion is given by the following equation:

$$\ln w_{ijt} = X'_{ijt}\beta_1 + \beta_2 TN_{ijt} + \beta_3 TN^2_{ijt} + \alpha_1 a^*_{jt} \cdot T + \alpha_2 \sigma^*_{jt} + \alpha_3 b_{jt} + u_3. \qquad (27.a)$$

$$u_3 = f_i + d_t + v_{ijt} \qquad (27.b)$$

where f_i is specific to individual i (individual component), independent across individuals but constant over time; d_t is specific to time t (time component); and v_{ijt} is specific to individual i in time period t (random error). The error term f_i and v_{ijt} are in general autocorrelated. However, f_i, d_t and v_{ijt} are assumed inde-

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30 Even though (UNEMPLOYMENT) is included in the relative product price equation, the business cycle effect on the earnings cannot be eliminated completely unless b_j are included on the r.h.s. of the earnings function. Note that high t-statistics of coefficient estimates on (unem on price) in earnings functions.

pendent each other, and, at a minimum, v_{ijt} is assumed independent of the regressors. In other words, the constant term in the regression changes for each year and each individual.

Note that T in equation (27.a) is the time index where it starts with T = 15 in 1978 and ends with T = 21 in 1983 in the case of 2-digit industry classification.[31] The reason why T is multiplied by a^*_{jt} and $a^*_{jt} \cdot T$, instead of a^*_{jt}, is included on the r.h.s. of equation (27.a) is in order to reflect the time effect correctly in the earnings function. Adams (1985), in a similar two-step procedure, includes a^*_{jt} on r.h.s. of the earnings function instead of $a^*_{jt} \cdot T$ (see footnote 24). If T is not multiplied, the time effects are misspecified in the variance components model.[32] The approach used here reflects the time effects more directly. Thus the time specific error component of a variance components model (d_t in equation (27.b)) provides a different interpretation from Adams (1985).

Both results using a^*_{jt} and $a^*_{jt} \cdot T$ on the r.h.s of the earnings function are shown in Table 3.d.[33] The results show, as expected, that the coefficient on $a^*_{jt} \cdot T$ in regressions (2) and (4) are larger than that on a^*_{jt} in regressions (1) and (3), and thus the time-specific error component in regressions (2) and (4) becames smaller

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31 In the case of 3-digit industry classification (data from the 1981 to the 1984 interview year), T = 15 in 1981, and T = 18 in the 1984 interview year.

32 If T is not multiplied, the time effects of the continuation of time-series regression are included in the time-specific error component in the variance components model.

than in regressions (1) (3). These results provide empirical support for the approach of including $a^{*}_{jt}\cdot T$ instead of a^{*}_{jt} on the r.h.s. of an earnings function. Thus all other tables report GLS regressions which include $a^{*}_{jt}\cdot T$ as an independent variable.

In equation (27.a), the coefficient, α_1, obtained on $a^{*}_{jt}\cdot T$ is the elasticity of the worker's wage with respect to the growth rate of industry j's relative product price. The coefficient, α_2, obtained on σ^{*}_{e}, is the cyclical sensitivity of worker i's wage. It is the elasticity of the wage with respect to transient change in the relative product price of the industry where he is currently working. There is one major difference between the present estimation and that of Adams (1985). Here α_1 reflects, as was discussed above, more direct effect of the trend of industry-specific product demand than the approach used in Adams (1985). The pooled GLS results of both 2-digit and 3-digit industry classifications are shown in Table 3.a through Table 3.d.

The estimates on human capital variables are standard in all tables. The interest here is, of course, the coefficients on the trend amount of log of relative industry product price (α_1) and cyclical deviations from trend (α_2). First, to see differences between first (ordinal pooled GLS regressions) and second approarch (pooled GLS regressions by merged data), compare regression (3) and (4) in Table 3.a and regression (1) and (3) in Table 3.b. Regression

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33 The seven-year panel data is used for the test since the time effects becomes larger as the period of sample observation is longer, and the difference of the two case becomes clear.

(4) in table 3.a and regression (3) in table 3.b are typical pooled GLS regression, which treats product prices as unobserved variables (first approach). If the proxies for firms' product prices are not included in a regression, because of the negative correlation between the error term and job tenure variables, the estimates on the wage-tenure profile are biased downward. Thus the coefficient estimates on both tenure and tenuresq in regression (4) report smaller values than that of regression (3) in both tables. Second, note that the estimates on a^*_{jt} and σ^*_{jt} become less significant if b_{jt} is not included in regressions. As it was mentioned before, this is because the earnings are affected by the business cycle as well as effects of industry-specific product demand.

In each table pooled GLS results by using different specifications are reported. Table 3.a and 3.b show the pooled GLS results for the samples of all races and whites using 3-digit industry classifications, respectively. There are some differences from the results in the cross sectional regressions. In the case of 3-digit industry classifications, the coefficients on cyclicality of industry-specific product demand becomes insignificant. This implies that the continuous pooled sample includes a mature set of workers with low tunrnover rates who are less prone to temporary shocks in product demand than the samples in the cross sectional regressions (remember that a worker has to be employed at the date of interview to be included in each sample). In the case of 2-digit classifications, on the other hand, the results show that the coefficients on price trends take negative signs although they are not significant. This implies that workers who show up in all seven years are more mature than the workers in the cross-sectional sample and the sample in four-year pooled GLS regressions, and the effects of industry product demand on wages themselves become less important than for less mature workers.[34]

To make the above argument clear, two subsamples are considered. The first subsample contains young workers (from 20 to 35 years old at the initial interview point), and the second contains workers with high job tenure (over 10 years of job tenure in the initial year). In order to conserve space, coefficients on the human capital variables are omitted from tables from now on. Such variables have standard coefficients. Complete results are available on request.

The results from the subsample of young workers strongly support Proposition 1. That is, wages tend to be greater in industries with high cyclical fluctuation as well as in growing industries. Results are shown in Tables 3.e and 3.f. This result is consistent with the theory of compensated wage differentials which says that a firm has to pay a wage premium to risk averse workers for variations in wage rates.[35] On the other hand, the results in the subsample of workers with high job tenure show significantly negative coefficient on cyclical fluctuations in industry product demand. This is opposite to the predictions of Proposition 1 in chapter II. See table

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34 It may also suggest that it is not appropriate to apply the stochastic nominal wage process (equation (5.a) and (5.b)) for a matured sample. However, since the coefficients on the cyclicality (σ_{it}) and b are significant, the results of this chapter still suggest that the effect of the product demand should be considered when an earnings function is estimated.

3.g.

Next, other demand variables are added to r.h.s of (27.a). There are two reasons for doing this. The first is to test how the estimates on industry-specific product demand are changed when general labor market conditions are included. The second is to test the existence of wage premiums because of differences in geographic and/or industry labor demand conditions. First, county and industry unemployment rates are included.[36] The equation to be estimated is

$$\ln w_{ijt} = X'_{ijt}\beta_1 + \tau_1 TN_{ijt} + \tau_2 TN^2_{ijt} + \alpha_1 a^*_{jt}\cdot T + \alpha_2 \sigma^*_e + \alpha_3 b_{jt} + \mu_1(IUNEM) + \mu_2(CUNEM) + u_4. \quad (28)$$

Since the employment rate also reflects labor demand condition of each industry, the following equation is also estimated.

$$\ln w_{ijt} = X'_{ijt}\beta_1 + \tau_1 TN_{ijt} + \tau_2 TN^2_{ijt} + \alpha_1 a^*_{jt}\cdot T + \alpha_2 \sigma^*_e + \alpha_3 b_{jt} + \mu_1(IEM) + u_5. \quad (29)$$

where u_4 and u_5 have the same error components as (27.b) and new

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35 Another interpretation is that young workers are more likely to be temporary laid off because of a temporary drop in product demand, and thus a firm has to pay a wage premium as compensated wage differentials for low job securities to retain them in periods of high product demand. However, this chapter takes the interpretation in the text since chapter II of this dissertation assumes no layoff probability.

36 County unemployment rates are directly available in the PSID. The U.S. Department of Labor, Bureau of Labor Statistics is the source of the data on industry unemployment.

demand variables are defined as follows:

IUNEM = industry unemployment rate;

CUNEM = county unemployment rate;

IEM = industry employment rate;[37]

Pooled GLS results by variance components models are given in Table 4.a through Table 4.f. The implications of the findings from the sample of prime aged male workers are as follows (see Table 4.a through 4.d). If labor market conditions are included, the effect of the trend in industry-specific product demand on the wages becomes less significant while the effect of cyclicality in product demand becomes more significant (except in the four-year white male sample). Concerning the sample of young workers, the inclusion of labor demand variables does not change the effects of industry-specific product demand on the wages. The effects of current industry employment and unemployment rates are not significant. However, the results indicate that wages are reduced in local markets (sectors) with low labor demand. This implies that current industry unemploymnet reflects short-term sectoral shifts that fail to induce labor mobility and therefore results in wage cuts. On the other hand, county unemployment rates have positive although insignificant effects on wages. This implies that there exist wage premiums because of differences in geographic labor demand condi-

37 IEM is defined as the ratio of total number of employees in each industry to total number in the U.S. labor force.

tion (see Adams (1985)).[38]

[3] Concluding Remarks

The present chapter shows the importance of product demand variables in estimating an earnings function when individual data are used. After eliminating the effect of macro business cycles, it found that as product demand becomes higher, the wage of workers rises. However, generally speaking, the effect of product demand is less important when a sample of mature people is used; that is, workers with long tenure and the workers who are observed continuously in the sample. Furthermore, this chapter found that as the product demand fluctuates more, wages tend to increase in the sample of young workers, but the wages tend to decrease in the sample of workers with long job tenure.

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38 It is interesting to compare the pooled GLS results in Adams (1985) with those in Table 4.c and Table 4.d (see also footnote 24). Adams merges demand variables and state UI replacement ratio with PSID data (he uses the data from the 1970 to the 1976 interview years). Although the purpose of the research and definitions or derivations of each variable are different, the main difference is that he includes state UI replacement ratios in the regression. He reports negative coefficients on state UI replacement ratio, industry growth and current industry unemployment rate although these are not significant, and a significant positive estimate on state unemployment rate.

Table 1

Means of Principal Demand Variables, All Races, 1981-84

variables	1981	1982	1983	1984
	year			
durable	0.3287	0.3985	0.3746	0.3744
nondurable	0.1972	0.2011	0.1955	0.2008
price trend	0.0027	0.0029	0.0043	0.0032
cyclical	0.0387	0.0414	0.0413	0.0409
unem on price	-0.0027	-0.0028	-0.0068	-0.0052
N	1871	1461	1469	1453

durable = 1 if he is in a durable manufacturing industry.
nondurable = 1 if he is in a nondurable manufacturing industry.
price trend = estimates on time trend in relative product price regressions.
cyclical = standard errors of estimates in relative product price regressions.
unem on price = estimates on the national unemployment rate in relative product price regressions.

Table 2.a

Cross-Sectional Wage Results, 1981-1984, All Races

variable	1981	1982	1983	1984
intercept	-0.40527	-0.26468	-0.37848	-0.42246
	(-6.368)	(-3.801)	(-5.212)	(-5.704)
tenure	0.01789	0.01485	0.01558	0.01594
	(13.002)	(10.432)	(9.966)	(10.038)
exp	0.00260	0.00519	0.00619	0.00711
	(2.626)	(4.628)	(5.054)	(5.575)
school	0.07768	0.08079	0.08428	0.08418
	(19.169)	(20.306)	(19.928)	(18.274)
married	0.23506	0.15111	0.13694	0.07879
	(11.695)	(5.488)	(4.709)	(2.774)
union	0.17984	0.13641	0.13320	0.15323
	(9.601)	(6.568)	(6.013)	(6.774)
durable	0.12466	0.12428	0.13696	0.17712
	(4.598)	(4.359)	(4.394)	(6.383)
nondurable	-0.01731	-0.04569	-0.01145	0.13265
	(-0.436)	(-1.010)	(-0.243)	(3.061)
price trend	-0.01364	0.53122	3.06917	3.72681
	(-0.011)	(0.466)	(2.698)	(3.884)
cyclical	1.92259	1.02390	1.74457	-0.24578
	(2.640)	(1.387)	(2.270)	(-0.361)
unem on price	4.23100	5.13430	6.18400	4.62757
	(5.049)	(6.660)	(7.943)	(6.424)
N	1871	1461	1469	1453
R^2	0.4414	0.3758	0.3829	0.3999

Numbers in parentheses are t-statistics.

tenure = number of year of job tenure in his current job.
exp = number of years of labor force experience after schooling.
school = number of year of schooling completed.
married = 1 if he is married.
union = 1 if the job is coverd by a collective bargaining.

Table 2.b

Cross-Sectional Wage Results, 1981-1984, White

variable	1981	1982	1983	1984
	year			
intercept	-0.33655	-0.04401	-0.10164	-0.24592
	(-3.747)	(-0.488)	(-1.105)	(-2.560)
tenure	0.01813	0.01583	0.01602	0.01604
	(10.810)	(9.897)	(9.187)	(8.915)
exp	0.00292	0.00310	0.00419	0.00604
	(2.296)	(2.373)	(2.915)	(4.088)
school	0.07904	0.07300	0.07411	0.08542
	(14.919)	(14.683)	(14.257)	(15.373)
married	0.23025	0.09836	0.09206	0.04087
	(8.195)	(2.656)	(2.447)	(1.078)
union	0.15606	0.10222	0.07424	0.12738
	(6.119)	(4.021)	(2.745)	(4.436)
durable	0.11626	0.11346	0.14787	0.20187
	(3.284)	(3.332)	(3.941)	(5.961)
nondurable	-0.00970	-0.00699	0.01459	0.15604
	(-0.183)	(-0.127)	(0.249)	(2.800)
price trend	-1.09658	0.17450	3.50928	4.41104
	(-0.681)	(0.125)	(2.493)	(3.734)
cyclical	1.64743	1.03569	1.22351	-0.66912
	(1.853)	(1.217)	(1.361)	(-0.791)
unem on price	3.70147	3.49899	5.91084	5.16478
	(3.463)	(3.630)	(6.120)	(5.857)
N	1110	963	983	975
R^2	0.3892	0.3270	0.3410	0.3602

Numbers in parentheses are t-statistics.

Table 3.a

Pooled GLS Results, 1981-84, ALL Races
(number = 3268)

variable	(1)	(2)	(3)	(4)
intercept	-0.0699	-0.07419	-0.14648	-0.15503
	(-0.987)	(-1.032)	(-2.036)	(-2.143)
tenure	0.01141	0.01124	0.01504	0.01430
	(9.067)	(8.855)	(5.459)	(5.172)
tenuresq			-0.00014	-0.00012
			(-1.611)	(-1.370)
exp	0.00675	0.00673	0.01933	0.01942
	(6.371)	(6.303)	(5.791)	(5.768)
expsq			-0.00027	-0.00027
			(-3.898)	(-3.914)
school	0.06944	0.07018	0.06579	0.06725
	(15.286)	(15.195)	(14.330)	(14.458)
white	0.14755	0.15124	0.15718	0.16020
	(5.829)	(5.860)	(6.231)	(6.236)
married	0.05619	0.05654	0.05268	0.05326
	(2.724)	(2.729)	(2.563)	(2.581)
union	0.05442	0.05380	0.04865	0.04905
	(3.345)	(3.283)	(2.996)	(3.001)
durable	0.09082	0.07604	0.09152	0.05852
	(4.166)	(3.491)	(4.217)	(2.992)
nondurable	0.04784	0.07081	0.09596	0.05418
	(1.761)	(2.638)	(1.833)	(2.321)
price trend	0.14071	0.08483	0.14433	
	(3.548)	(2.241)	(3.650)	
cyclical	-0.04781	-0.36346	-0.00836	
	(-0.143)	(-1.109)	(-0.025)	
unem on price	2.22915		2.26967	
	(4.689)		(4.785)	
σ_i	0.09099	0.09565	0.08940	0.09384
σ_t	0.00012	0.00014	0.00013	0.00012
σ_v	0.03576	0.03557	0.03500	0.03512

Numbers in parentheses are t-statistics.
σ_i, σ_t, and σ_v are standard deviation of variance components for individuals, time, and error.

Table 3.b

Pooled GLS Results, 1981-84, White
(number = 2248)

variable	(1)	(2)	(3)	(4)
intercept	0.27876	0.28671	0.27694	0.17768
	(3.307)	(3.367)	(3.286)	(2.082)
tenure	0.01217	0.01198	0.01099	0.00924
	(9.067)	(9.049)	(8.061)	(2.987)
tenuresq				-0.00009
				(-1.000)
exp	0.00292	0.00277	0.00279	0.02350
	(2.548)	(2.401)	(2.422)	(6.023)
expsq				-0.00046
				(-5.460)
school	0.06125	0.06137	0.06162	0.05742
	(12.262)	(12.139)	(12.261)	(11.492)
married	0.02551	0.02686	0.02759	0.02090
	(1.000)	(1.028)	(1.057)	(0.888)
union	0.06664	0.06711	0.06675	0.06245
	(3.435)	(3.435)	(3.420)	(3.227)
durable	0.08112	0.06533	0.05781	0.08764
	(3.292)	(2.660)	(2.639)	(3.578)
nondurable	0.05836	0.08779	0.07612	0.06518
	(1.859)	(2.849)	(2.811)	(2.091)
price trend	0.09301	0.01909		0.11026
	(1.960)	(0.444)		(2.337)
cyclical	0.00691	-0.30415		-0.02459
	(0.011)	(-0.778)		(-0.067)
unem on price	2.54214			2.54528
	(4.379)			(4.420)
σ_i	0.08126	0.08424	0.08408	0.07907
σ_t	0.00011	0.00009	0.00011	0.00008
σ_v	0.03431	0.03437	0.03434	0.03377

Numbers in parentheses are t-statistics.
σ_i, σ_t, and σ_v are standard deviation of variance components for individuals, time, and error.

Table 3.c

Pooled GLS Results, 1978-84, ALL Races
(number = 2268)

variable	(1)	(2)	(3)
intercept	-0.55632	-0.54015	-0.62681
	(-8.377)	(-8.094)	(-9.374)
tenure	0.00374	0.00263	0.00440
	(2.508)	(1.770)	(1.275)
tenuresq			-0.00002
			(0.161)
exp	0.01407	0.01382	0.03735
	(11.343)	(11.087)	(8.798)
expsq			-0.00070
			(-5.796)
school	0.07947	0.07734	0.07340
	(18.746)	(18.215)	(16.999)
white	0.18110	0.18204	0.18531
	(9.297)	(9.285)	(9.603)
married	0.21870	0.22532	0.21279
	(12.398)	(12.729)	(12.140)
union	0.14062	0.14459	0.13621
	(8.398)	(8.590)	(8.194)
durable	0.11359	0.11867	0.13621
	(5.631)	(5.853)	(8.194)
nondurable	0.05981	0.06079	0.04018
	(2.416)	(2.441)	(1.622)
price trend	-0.01355	0.03004	-0.09578
	(-0.772)	(1.928)	(-0.548)
cyclical	0.51845	0.59635	0.52857
	(4.3170)	(4.9754)	(4.4267)
unem on price	1.79331		1.74552
	(5.298)		(5.173)
σ_i	0.04990	0.05080	0.04716
σ_t	0.00002	0.00001	0.00003
σ_v	0.06934	0.06976	0.06838

Numbers in parentheses are t-statistics.
σ_i, σ_t, and σ_v are standard deviation of variance components for individuals, time, and error.

Table 3.d

Pooled GLS Results, 1978-84, White
(number = 903)

variable	(1)	(2)	(3)	(4)
intercept	0.16895	0.16796	0.13704	0.13598
	(1.020)	(1.015)	(0.824)	(0.818)
tenure	0.00859	0.00860	0.08846	0.00886
	(3.785)	(3.792)	(3.897)	(3.904)
tenuresq			-0.00020	-0.00021
			(-2.100)	(-2.190)
exp	0.01096	0.01010	0.02235	0.02237
	(4.312)	(4.325)	(3.286)	(3.290)
expsq			-0.00035	-0.00035
			(-1.802)	(-1.799)
school	0.05567	0.05577	0.05261	0.05273
	(5.337)	(5.348)	(4.982)	(4.995)
married	0.12060	0.12055	0.12001	0.11997
	(3.608)	(3.607)	(3.596)	(3.595)
union	0.08922	0.08934	0.09286	0.09296
	(2.589)	(2.593)	(2.694)	(2.697)
durable	0.04175	0.04160	0.03029	0.03013
	(0.943)	(0.940)	(0.678)	(0.675)
nondurable	-0.00960	-0.00961	-0.02140	-0.02143
	(-0.169)	(-0.169)	(-0.375)	(-0.376)
a^*_{jt}	-0.34693		-0.30514	
	(-0.689)		(-0.606)	
$a^*_{jt} \cdot T$		-0.02077		-0.01888
		(-0.819)		(-0.745)
cyclical	0.18111	0.17673	0.18219	0.17789
	(0.989)	(0.963)	(0.995)	(0.971)
unem on price	1.06453	1.0959	1.07707	1.10949
	(2.180)	(2.230)	(2.205)	(2.257)
σ_i	0.08267	0.08266	0.08240	0.08239
σ_t	0.00046	0.00044	0.00049	0.00047
σ_v	0.04490	0.04489	0.04479	0.04478

Numbers in parentheses are t-statistics.
σ_i, σ_t, and σ_v are standard deviation of variance components for individuals, time, and error.

Table 3.e
Pooled GLS Results, 1981-84, All Races, Age 20-35
(number = 1716)

variable	(1)	(2)
durable	0.12013	0.12478
	(6.376)	(4.910)
nondurable	0.01264	0.00898
	(0.356)	(0.254)
price trend	0.13264	0.12381
	(1.464)	(2.276)
cyclical	1.46410	1.52962
	(2.725)	(2.850)
unem on price	5.27773	5.27707
	(9.092)	(9.108)
σ_i	0.03967	0.03901
σ_t	0.00001	0.00001
σ_v	0.07814	0.07801

Numbers in parentheses are t-statistics.
Regression (1) does not include the square term of full-time work experience and job tenure. Regressions (2) includes those variables.

Table 3.f
Pooled GLS Results, 1978-84, All Races, Age 20-35
(number = 819)

variable	(1)	(2)
durable	0.00457	0.00440
	(0.108)	(0.104)
nondurable	-0.07153	-0.08447
	(-1.485)	(-1.760)
price trend	0.01953	0.01837
	(1.099)	(1.038)
cyclical	0.38057	0.37019
	(3.058)	(2.988)
unem on price	0.54499	0.66008
	(1.478)	(1.790)
σ_i	0.07354	0.07151
σ_t	0.00050	0.00046
σ_v	0.03699	0.03582

Numbers in parentheses are t-statistics.

Table 3.g
Pooled Wage Results, 1981-84, ALL Races, Tenure>10 in 1981
(number = 1228)

variable	(1)	(2)
durable	0.13624	0.13412
	(3.986)	(3.916)
nondurable	0.09969	0.09775
	(2.343)	(2.296)
price trend	0.11611	0.11433
	(1.993)	(1.963)
cyclical	-0.83318	-0.83261
	(-1.914)	(-1.804)
unem on price	1.22947	1.22365
	(1.810)	(1.804)
σ_i	0.08345	0.08351
σ_t	0.00009	0.00008
σ_v	0.02094	0.02089

Numbers in parentheses are t-statistics.

Table 4.a
Pooled GLS Results, 1978-84, ALL Races
(number = 2268)

variable	(1)	(2)
durable	0.11624	0.10207
	(5.538)	(4.875)
nondurable	0.06286	0.04346
	(2.521)	(1.742)
price trend	-0.00626	-0.00278
	(-0.354)	(-0.158)
cyclical	0.58585	0.59192
	(4.803)	(4.882)
unem on price	1.47210	1.43143
	(3.910)	(3.816)
industry unem	-0.00100	-0.00122
rate	(-0.414)	(-0.503)
county unem	0.00098	0.00091
rate	(2.523)	(2.348)
σ_i	0.05003	0.04729
σ_t	0.00004	0.00005
σ_v	0.06872	0.06842

Numbers in parentheses are t-statistics.

Table 4.b
Pooled GLS Results, 1978-84, White
(number = 903)

variable	(1)	(2)
durable	0.05074	0.03947
	(1.131)	(0.872)
nondurable	-0.00239	-0.01448
	(-0.042)	(-0.248)
price trend	-0.01627	-0.01448
	(-0.638)	(-0.568)
cyclical	0.20884	0.21022
	(1.131)	(1.139)
unem on price	0.81958	0.83556
	(1.577)	(1.608)
industry unem	-0.00408	-0.00410
rate	(-1.312)	(-1.318)
county unem	0.00036	0.00035
rate	(0.611)	(0.590)
σ_i	0.08150	0.08122
σ_t	0.00027	0.00031
σ_v	0.04494	0.04483

Numbers in parentheses are t-statistics.

Table 4.c
Pooled GLS Results, 1981-84, ALL Races
(number = 3268)

variable	(1)	(2)
durable	0.09113	0.09126
	(4.082)	(4.107)
nondurable	0.04756	0.04976
	(1.742)	(1.828)
price trend	0.14009	0.14483
	(3.452)	(3.578)
cyclical	-0.04356	-0.01079
	(-0.129)	(-0.032)
unem on price	2.22289	2.27057
	(4.628)	(4.739)
industry	0.03743	-0.02643
employment rate	(0.072)	(-0.051)
σ_i	0.09104	0.08942
σ_t	0.00013	0.00014
σ_v	0.03518	0.03499

Numbers in parentheses are t-statistics.

Table 4.d
Pooled GLS Results, 1981-84, White
(number = 2248)

variable	(1)	(2)
durable	0.08563	0.09315
	(3.392)	(3.714)
nondurable	0.05452	0.06049
	(1.716)	(1.919)
price trend	0.08592	0.10163
	(1.779)	(2.118)
cyclical	0.04766	0.02656
	(0.111)	(0.067)
unem on price	2.46105	2.44743
	(4.179)	(4.192)
industry	0.47980	0.58657
employment rate	(0.888)	(1.000)
σ_i	0.08119	0.07892
σ_t	0.00011	0.00008
σ_v	0.03432	0.03379

Numbers in parentheses are t-statistics.

Table 4.e
Pooled GLS Results, 1981-84, All Races, Age 20-35
(number = 1716)

variable	(1)	(2)
durable	0.12786	0.12679
	(4.947)	(4.916)
nondurable	0.01395	0.01017
	(0.392)	(0.286)
price trend	0.12810	0.11985
	(2.327)	(2.176)
cyclical	1.49210	1.55388
	(2.763)	(2.881)
unem on price	5.21198	5.21947
	(8.780)	(8.807)
industry	0.39538	0.34523
employment rate	(0.530)	(0.463)
σ_i	0.03974	0.03907
σ_t	0.00001	0.00001
σ_v	0.07811	0.07798

Numbers in parentheses are t-statistics.

Table 4.f
Pooled GLS Results, 1978-84, ALL Races, Age 20-35
(number = 819)

variable	(1)	(2)
durable	0.00723	0.00881
	(0.169)	(0.207)
nondurable	-0.07045	-0.08296
	(-1.460)	(-1.727)
price trend	0.01951	0.01854
	(1.096)	(1.046)
cyclical	0.38259	0.37432
	(3.066)	(3.015)
unem on price	0.50541	0.59189
	(1.324)	(1.554)
industry unem	-0.00124	-0.00201
rate	(-0.766)	(-0.766)
county unem	0.00038	0.00039
rate	(0.534)	(0.523)
σ_i	0.07366	0.07163
σ_t	0.00054	0.00049
σ_v	0.03610	0.03587

Numbers in parentheses are t-statistics.

Chapter IV

Estimation of a Wage Offer Function

[1] Introduction and the Model

The purpose of this chapter is to correct a possible censoring and/or self-selectivity problem in the observed wage data. In a job matching there is a wage determination process: an employer determines a wage offer, and an employee decides to accept or reject the offer. Observed wage data[39] in cross-sectional and panel data are actually the wages that are offered by employers and accepted by employees before the interview date, given possible outside options for both parties. If a worker moves to another firm, the observed data are the wage offers from the new firm. Thus empirical work presented here is related to the one developerd by Marshall and Zarkin (1987) in this respect.

This chapter considers the wage contract that is assumed by Marshall and Zarkin (1987). The model is different from the one constructed in chapter II and chapter III although heterogeneous employers and employees are assumed. A firm is assumed to produce one product at a single market price which changes over time. This

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39 Note that the PSID has two type of wage data. The first one is the average hourly wage rate (total income of a household head divided by total working hours in the previous year). This wage data is used in chapter 3. The second one is the current hourly wage rate at the interview date. The latter one is explained in section 2 of this chapter.

chapter assumes that a wage renegotiation for next year is occured once a year and a new contract has one-year duration. A firm determines an offered wage based on the amount of a worker's skill and on the firm's expected relative product demand in next year. A worker decides whether he accepts the offer or rejects it, given possible outside job offers and an option to be unemployed. He stays in the firm if the wage offer is equal to or higher than his reservation wage. In a wage renegotiation, a worker's productivity and his firm's current and past product demand are common knowledge. However, the firm's product demand in next period is a stochastic part of the wage renegotiation. The firm and the worker try to estimate it by looking at the current and the past movement of relative product demand. The firm will do so in order to decide the wage offers and the number of new hires and layoffs for next year. On the other hand, the worker does so to calculate the present value of the job and to determine the reservation wage, given some outside job offers.

The main contribution of this chapter is to estimate a wage offer function by correcting possible censoring and/or self-selectivity problems. The data from the 1983 and the 1984 interview years of the Panel Study of Income Dynamics (PSID) are used and merged with industry price indices and other demand variables. A trend and a cyclical deviation from the trend are calculated in the same way as in chapter III. A worker stays in the same firm if the wage offer is equal to or higher than his reservation wage. In the opposite case, he turns down the offer and leaves the firm. If he decides to leave and he finds a new job successfully between two interview dates in panel data, the observed wage data is a wage offer by the new firm. Thus the wage offer made by his previous firm is not observed in this case. If he has not yet completed his job search process, he is defined as unemployed. The chapter estimates the effect of job tenure on wage offers by correcting a censoring problem, and also a self-selectivity problem if the worker voluntarily terminates his previous job and finds a new job. The statistical technique underlying the estimates is censoring-correction model and maximum-likelihood estimates of the switching-regime model where the switching is endogenously determined. See Heckman (1978, 1979), Lee and Trost (1978), and Lee (1979). In this chapter, the two groups are stayers and leavers.

A wage offer function is estimated by a three-step procedure. First, using price indices for industries, a trend and a cyclical deviation from the trend for each industry-specific product demand are calculated by time-series regressions. Second, those variables are included on the r.h.s. of a wage offer function as independent variables in addition to standard human capital variables. Third, the maximum-likelihood estimates of the switching-regime model are derived.

The following section explains the merged data set. Section 3 explains the identification problem and develops the econometric model. Empirical findings and their implications are presented in section 4. The statistical superiority of the model with product demand variables is also shown. Section 5 provides some concluding remarks.

[2] The Data Set

The PSID is used to obtain a sample of prime aged male household heads and is merged with the published data on industry prices. There is one major difference in the wage data between chapter III and this chapter. This chapter uses the hourly wage rates at exactly the date of interview. The PSID includes the information whether a worker is paid by the hourly rate or is salaried. Then the current hourly wage rates are provided for the former group and the hourly wage rates are calculated and given for the latter.[40] This data is used as the observed wage offers for the purpose here.

Concerning the industy price data, workers are classified into 30 industries.[41] In order to find the appropriate matching of a price index and an industry, there is a restiction on the number of industries included in the sample. About fifty percent of workers in the samples are in manufacturing. The sample includes workers who are heads of households and are employed in manufacturing, transportation, public utility, and service industry. See appendix 6 for industries to be included in the sample. Although this is a disadvantage of this approach, the price indices are the best available

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40 Those who are paid by other type of payments are deleted from the sample.

41 There are some differences in industry classifications. In this chapter, 1) the business and repair services industry are included; 2) public utility industry is divided into three industries; 3) professional and related services are divided into five industries instead of three industries. For details, see appendix 6.

proxies for firms' product prices.

To be included in the sample the worker had to meet the following criteria: (1) employed in both the 1983 and the 1984 interview year, (2) not self-employed, (3) a full-time employee. In addition if current job tenure exceeded current full-time labor force experience, then the worker was deleted from the sample.[42]

The sample size is 1245, 153 of them permanemtly separated from the previous firms between two interview dates. Descriptive statistics for the variables used in estimating a wage offer function are presented in table 5. Stayers have longer job tenure in 1983 than job leavers. Furthermore, stayers are paid more, have more full-time labor market experience, work more in growing industries with high cyclical fluctuations of product demand, are more likely to be married, and their wives' income are higher. However, movers are slightly better educated and the percentage of white is higher. The precise definition of the variables are shown in table 5.

[3] Identification and the Econometric Model

This section presents the estimation technique of a wage offer function. The estimation of the wage offer function follows a three-step procedure. At first, as a proxy variable for a firm's product price, either the consumer or producer price index pertaining to the

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42 Although the PSID does not include the individuals charcterized by substantial job turnovers like the National Longitudinal Survey of Young Men that Marshall and Zarkin (1987) used, the data are good enough for the purpose here.

industry in which each respondent works is used. A trend and a cyclical fluctuation of the relative product price of each industry are calculated from a time-series regression based on the most recent fifteen years of evidence. In this chapter the data of industry price indices from 1969 to 1983 are used since the observed wage data are assumed to be determined anywhere from 0 to 12 months prior to the interview date (one day in 1983 or early in 1984 in this case). In other words, both a worker and a firm are assumed to use the available information of the firm's product demand. The time-series regressions to be estimated are

$$\ln (p_{jt}/CPI_t) = \Phi_j + a_j(TIME) + b_j(UNEMPLOYMENT) + e_j \quad (30)$$

where p_{jt} is producer (or consumer) price index of industry j (worker i's industry), CPI_t is the average consumer price index in year t, TIME is a time index which starts in 1969 and ends in 1983, and UNEMPLOYMENT is men's national unemployment rate of twenty-years-old and over. Predicted values, a_j, are trend amounts of log of relative industry product price, while σ_j (standard error of esimate), are cyclical deviations from trends, and Φ_j is the constant term. Note that these values are industry specific. Regressions are run in 30 industries by using 3-digit industry classifications. The reason that UNEMPLOYMENT is included in regressors is to eliminate the effect of macro business cycle. If the variable is not included, the estimates in time-series regressions also pick up the effect of business cycle and the estimates of the regressions do not provide the effect of shifts and cyclical shocks in industry-specific product demand.

Second, the variables, a_j, b_j, and σ_j are included on the r.h.s. of a wage offer function as independent variables in addition to standard human capital variables. However, note that the observed wage data in the 1984 interview year is determined by the wage renegotiation anywhere from 0 to 12 prior to the date of the information by using the information of the firm's relative product demand up to 1983. Thus, those product demand variables are included as of time period, t-1, in the wage offer function. The wage offer function to be estimated is

$$\ln w_{ij} = X'_{i,-1}\beta_1 + \tau_1 TN_{ij} + \tau_2 TN^2_{ij} + \alpha_1 a_{j,-1} + \alpha_2 \sigma_{j,-1} + \alpha_3 b_{j,-1} + e_{ij} \quad (31)$$

where TN_{ij} is worker i's year of job tunure in firm j at the interview date, X_i vector contains information on worker characteristics and e_{ij} is assumed to be i.i.d. error component. Thus the wage offer in next period is determined by the amount of a worker's general human capital and firm-specific skill, and the firm's relative product demand in next year. The above wage offer function is different from a usual one since it takes firms' expected product demand into consideration. See table 5 for precise definitions of the variables.

The reason that X' vector of the previous period (-1) is included in regressors is as follows. In this chapter, a wage renegotition between a worker and a firm is assumed to occure once a year and the wage contract is assumed to have one-year duration.

Thus, an observed wage in the data is assumed to be set at the date from 0 to 12 months prior to the interview date. The data on worker charcteristics are the information at exactly the date of interview. Thus it is more appropriate to use the data in the previous interview year if this type of wage contracts are assumed. This is the same idea that is proposed by Marshall and Zarkin (1987). Thus, information on worker charcteristics in the 1983 interview year is used in estimating a wage offer function based on the wage data in the 1984 interview year here.

In equation (31) the coefficient, α_1, obtained on $a_{j,-1}$ shows the amount of increase in the worker's wage with respect to an increase in industry j's relative product price. The coefficient, α_2, obtained on $\sigma_{j,-1}$, is the cyclical sensitivity of worker i's wage. It is the amount of an increase in the wage with respect to transient change in the relative product price pertaing to the industry where he is currently working.

The tenure variable is equal to zero if an individual left a firm j and found a new employment at firm k between the last and current interview date. If equation (31) is estimated by OLS, the parameter estimates will be biased because of a censoring problem which concerns the variable TN_{ij} and TN^2_{ij}. To get unbiased OLS parameter estimates, the censoring problem has to be corrected. The censoring correction to be employed is based on evaluation of $E(e_{ij}|TN_{ij})$ or on the expectation of the error term from the wage-offer equation conditional on whether the worker stays at ($TN_{ij} \geq 1$) or leaves the firm ($TN_{ij} = 0$) (see Marshall and Zarkin (1987)).

Here two assumptions in equation (31) are relaxed. First, the error structure associated with wage offers for movers (new hires) is now assumed to be different from the error structure for stayers. Second, firms are assumed to utilize the information contained in $X_{i,-1}$ in different ways for new hires (firm k) versus stayers (firm j). These relaxations are the same as formulating a switching-regime model. Following the same idea in chapter III and the econometric model developed by Lee and Trost (1978), the present chapter formulates a switching-regime model where regime 1 is stayers and regime 2 is leavers. Note that a switching-regime model can be applied here since the sample observation belonging to different regimes (stayers or leavers) are distinguished in the data.

Given that a worker is allowed to do on-the-job search or to be unemployed for full-time search, he remains at a firm if his reservation wage is greater than the wage offered by the firm. Suppose worker i is working for firm j in time period t - 1, firm j's wage-offer and worker i's reservation wage function for period t are defined as

$$\ln w^o_{ij} = X'_{i,-1}\beta_1 + \tau_1 \cdot TN_{ij} + \tau_2 \cdot TN^2_{ij} + \alpha_1 a_{j,-1} + \alpha_2 \sigma_{j,-1} + \alpha_3 b_{j,-1} + e^o_{ij}, \quad (32)$$

$$\ln w^r_{ij} = X'_{i,-1}\beta_3 + Z'_{i,-1}\beta_4 + \tau_3 \cdot TN_{ij} + \tau_4 \cdot TN^2_{ij} + \alpha_4 a_{j,-1} + \alpha_5 \sigma_{j,-1} + \alpha_6 b_{j,-1} + e^r_{ij} \quad (33)$$

where $\ln w^o_{ij}$ is the log of the offerd wage rate by a firm, $\ln w^r_{ij}$ is the log of the reservation wage rate, and $Z_{i,-1}$ is a vector of personal, household, and labor market characteristics for worker i in period t - 1, which serves as a proxy for mobility and search costs, and both e^{o}_{ij} and e^{r}_{ij} are i.i.d. error components. In probit estimates for stay-or-leave decision, appropriate price indices from 1969 to 1983 are used as proxy variable for firm j's relative product demand. Both worker i's reservation wage and firm j's wage offer are formulated conditional on worker i's job tenure at a firm, other human capital variable, and situation of firm j's product demand. In other words, for worker i's stay-or-leave decision, other relevant variables for his mobility and job search process are included in addition to the above variables.

Note a difference between equations (31) and (32). The dependent variable in equation (31) is acceptable wage offers and it is always observable. On the other hand, the dependent variable in equation (32), $\ln w^{o}_{ij}$ is unobservable if $TN_{ij} = 0$. It is because that equation (32) describes how firm j sets wage offers at the time of wage contract negotiations whether or not these wages are observed. Whether worker i stays at firm j depends on the relation between $\ln w^{o}_{ij}$ and $\ln w^{r}_{ij}$ and the worker stays at the firm, or $TN_{ij} \geq 1$, if

$$\ln w^{o}_{ij} - \ln w^{r}_{ij} \geq 0, \text{ or if}$$

$$X'_{i,t-1}(\beta_1 - \beta_3) - Z'_{i,t-1}\beta_4 + (\tau_1 - \tau_3)TN_{ij} + (\tau_2 - \tau_4)TN^2_{ij}$$
$$+ (\alpha_1 - \alpha_4)a_{j,-1} + (\alpha_2 - \alpha_5)\sigma_{j,-1} + (\alpha_3 - \alpha_6)b_{j,-1}$$
$$\geq e^{r}_{ij} - e^{o}_{ij} \quad (33)$$

Let

$$Q_i = (X'_{i,-1}, Z'_{i,-1}, TN_{ij}, TN_{ij}^2, a_{j,-1}, \sigma_{j,-1}, b_{j,-1}) \quad (34)$$

$$R' = (\beta_1 - \beta_3, -\beta_4, \tau_1 - \tau_3, \tau_2 - \tau_4, \alpha_1 - \alpha_3, \alpha_2 - \alpha_4, \alpha_3 - \alpha_6) \text{ and}$$

$$v_i = e_{ij}^r - e_{ij}^o \qquad (35)$$

Then the condition (33) becomes $Q_iR \geq v_i$. On the other hand, worker i leaves a firm, or $TN_{ijt} = 0$, if $Q_iR < v_i$. A dichotomous variable I_i which is defined as $I_i = 1$ iff $Q_iR \geq v_i$, and $I_i = 1$ iff $Q_iR < v_i$. Then the switching-regime model is defined as follows:

<u>Regime 1</u>: (<u>stayers</u>);

$$\ln w_{ij} = X'_{i,-1}\beta_1 + \tau_1 TN_{ij} + \tau_2 TN_{ij}^2$$
$$+ \alpha_1 a_{j,-1} + \alpha_2 \sigma_{j,-1} + \alpha_3 b_{j,-1} + e_{i1}, \qquad (36)$$

$$\text{iff } Q_iR \geq v_i \text{ or } I_i = 1;$$

Regime 2: (leavers);

$$\ln w_{ik} = X'_{i,-1}\beta_2 + \alpha_7 a_{k,-1} + \alpha_8 \sigma_{k,-1} + \alpha_9 b_{k,-1} + e_{i2} \quad (37)$$

$$\text{iff } Q_iR < v_i \text{ or } I_i = 0.$$

Note that if worker i moves to firm k (a new firm), the observed wage of worker i is the one from firm k, and depends on firm k's product demand. Thus, for the mover, the demand variables included in the probit equation is different from the those variables in a wage offer function. With the assumption that v_i is normally distributed, the above relation becomes the following probit model:

$$I_i^* = Q_i R - v_i, \quad (38)$$

with $I_i = 1$ iff $I_i = 0$ otherwise. Thus it follows that $I_i = F(Q_i R/\sigma_v) + U_i$ where F is cumulative distribution of the standard normal variate v_i. For both regime 1 and regime 2,

$$\begin{bmatrix} e_{i1} \\ e_{i2} \\ v_i \end{bmatrix} \sim N \left[\begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_1^2 & \sigma_{12} & \sigma_{1v} \\ \sigma_{21} & \sigma_2^2 & \sigma_{2v} \\ \sigma_{v1} & \sigma_{v2} & 1 \end{pmatrix} \right]$$

It can be easily shown that $E[I_i v_i] = \sigma_{1v}[-f(Q_i R)]$, and $E[(1 - I_i)v_i] = \sigma_{2v} f(Q_i R/)$. It follows that

$$E(e_{i1} | Q_i R \geq v_i) = -\sigma_{1v} \cdot \frac{f(Q_i R)}{F(Q_i R)} \quad (39)$$

$$E(e_{i2} | Q_i R < v_i) = \sigma_{2v} \cdot \frac{f(Q_i R)}{1 - F(Q_i R)} \quad (40)$$

Hence,

$$E[\ln w_{ij} | I_i = 1] = X'_{i,-1}\beta_1 + \tau_1 TN_{ij} + \tau_2 TN_{ij}^2 + \alpha_1 a_{j,-1} + \alpha_2 \sigma_{j,-1} + \alpha_3 b_{j,-1} - \sigma_{1v} \frac{f(Q_i R)}{F(Q_i R)}, \quad (41)$$

$$E[\ln w_{ij} | I_i=0] = X'_{i,-1}\beta_2 + \alpha_7 a_{k,-1} + \alpha_8 \sigma_{k,-1} + \sigma_9 b_{k,-1} + \sigma_{2v} \cdot \frac{f(Q_i R)}{1 - F(Q_i R)}. \quad (42)$$

After adding disturbance terms with zero means, the equations become

$$\ln w_{ij} = X'_{i,-1}\beta_1 + \tau_1 TN_{ij} + \tau_2 TN_{ij}^2 + \alpha_1 a_{j,-1} + \alpha_2 \sigma_{j,-1} + \alpha_3 b_{j,-1} - \sigma_{1v} \cdot \frac{f(Q_i R)}{F(Q_i R)} + \mu_{i1}, \quad (43)$$

$$\ln w_{ij} = X'_{i,-1}\beta_2 + \alpha_7 a_{k,-1} + \alpha_8 \sigma_{k,-1} + \alpha_9 b_{k,-1} + \sigma_{2v} \cdot \frac{f(Q_i R)}{1 - F(Q_i R)} + \mu_{i2}. \quad (44)$$

where $E[\mu_{i1} | I_i=1] = 0$ and $E[\mu_{i2} | I_i=0] = 0$.

Given the above equations, well-known two-stage estimation procedure can be applied. The probit model is estimated in the first stage,

$$I_i = F(Q_i R) + U_i, \quad (45)$$

in order to get consistent estimate R^* of R. The maximum likelihood estimates R^* can be obtained by the iteration procedure. In the second stage, R^* is substituted into the wage equations, and consistent and unbiased coefficient estimates are available by OLS. The equations are

$$\ln w_{ij} = X'_{i,-1}\beta_1 + \tau_1 TN_{ij} + \tau_2 TN_{ij}^2 + \alpha_1 a_{j,-1} + \alpha_2 \sigma_{j,-1}$$

$$+ \alpha_3 b_{j,-1} - \sigma_{1v} \cdot \frac{f(Q_i R^*)}{F(Q_i R^*)} + \mu'_{i1}, \qquad (46)$$

$$\ln w_{ij} = X'_{i,-1}\beta_2 + \alpha_7 a_{k,-1} + \alpha_8 \sigma_{k,-1} + \alpha_9 b_k$$

$$+ \sigma_{2v} \cdot \frac{f(Q_i R^*)}{1 - F(Q_i R^*)} + \mu'_{i2}. \qquad (47)$$

With the sample observation of stayers, β_1, τ_1, τ_2, α_1, α_2, α_3, and σ_{1v} are estimated by OLS. Similarly, with the sample observation of leavers, β_2, α_7, α_8, α_9, and σ_{2v} are estimated by OLS. Although these OLS estimates are unbiased and consistent, they are not fully efficient. Maximum likelihood procedures (ML) have to be used to obtain efficient estimates. Initial estimates for all parameters, the variances and covariances have to be estimated for ML. Consistent estimation of σ_1^2, σ_2^2, σ_{1v}, and σ_{2v} are available by using second moments of the estimated residuals. However, σ_{12} cannot be estimated in the model since it is not identifiable. This fact is shown in the likelihood function which is given by

$$L(\beta_1, \beta_2, \tau_1, \tau_2, \alpha_1, \alpha_2, \alpha_3, \alpha_7, \alpha_8, \alpha_9, \sigma_1^2, \sigma_2^2, \sigma_{1v}, \sigma_{2v})$$

$$= \prod_{i=1}^{N} \left[\int_{-\infty}^{Q_i R} g(e_{i1}, v_i) dv_i \right]^{I_i} \left[\int_{Q_i R}^{\infty} f(e_{i2}, v_i) dv_i \right]^{1-I_i}$$

where $g(e_{i1}, v_i)$ is the bivariate normal density of e_{i1} and v_i and $f(e_{i2}, v_i)$ the bivariate normal density of e_{i2} and v_i. In the next section, following the above two-step procedure, the consistent and unbiased estimates for both regimes are shown. After that, ML are used to obtain efficient estimates.

[4] Empirical Findings and Interpretations

Table 6 shows OLS estimates with and without restrictions across regimes. Note that the estimates in table 6 are the results when no-censoring bias is assumed. First, all human capital variables (tenure, exp, school, tenuresq, expsq) take the expected signs and significant. Second, note that all regressions include product demand variables in regressors. All three regressions report that the wage offer increases as the product demand rises; that is, a wage offer tends to be higher in a growing industry. The effects of cycliclity of the product demand on the wage for stayers are negative although it is insignificant. For movers, its effect on the wage offer is positive and significant. This implies that firms with large cyclically fluctuations in product demand tend to pay higher wage offers than firms with steady product demand. For the sample of all workers its effect is negative but insignificant. Third, the coefficients on (tenure) and (tenuresq) have been reduced in both absolute magnitude and significance due to the relaxation of restriction on across-regime coefficient, which is consistent with the findings of Marshall and Zarkin (1987), and Mincer and Jovanovic (1981).

Table 7 reports the probit estimates for stay-or-move decision. The dependent variable is equal to one if a respondent worker stays in the same firm. All human capital variables included in regressions are similar to those variables in a usual job separation function (see, for example, Mincer and Jovanovic (1981)). The implication is exactly same as the results of estimates of the probability of a job separation. The probability of a job separation (both quits and layoffs) is a decresing function of a worker's job tenure. In other words, a worker stays longer as his job tenure rises. The most interesting results here are the estimates of the effects of the proxy variables for condition of product demand and the mobility and job search cost. Table 7 shows that a worker tends to stay in the same firm as his previous firm's product demand rises and the effect is significant. This is an interesting result since it suggests that the implication of the derived demand for labor hypothesis is important in estimating a job separation function (see chapter V in details). There is no significant effect of cyclical fluctuations of product demand on the probability of staying. Second, as both industry and county unemployment rates rises, a worker tends to leave his firm.[43] Third, a married household head tends to leave his firm as his wife's labor income increases.

Table 9 reports the result of a probit equation when the product demand variables are excluded. The coefficient estimate on tenure rises and the effect of industry unemployment rates become

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43 Note that many job changers have moved to a different labor market when they changed jobs between two interview dates since workers are classified into 30 industries. In other words, unemployment rates are considered as indicators to show whether local labor markets are promising rather than those of showing the easiness to find new jobs. Thus these results make sense intuitively since workers tend to move to promising firms.

significant. (see footnote 43).

Table 8 reports the fully efficient estimates by ML. There are several differences between OLS estimates in table 6 and ML estimates in table 8. At first, the coefficients on (tenure) and (tenuresq) have decreased in both absolute magnitude and the t-statistics. Secondly, the censoring correction for stayers are insignificant although it is significant for movers. The positive sign of the coefficient estimate on σ_{1v} and negative sign of the estimate on σ_{2v} imply that the variance in reservation wages is larger than the variance of wage offers for stayers, and the opposite case occurs for leavers.[44] For the coefficient estimates on the trends of product demand drop for both regime and the estimate for leavers has become insignificant at 5% level. Negative estimate on the cyclical fluctuations is almost the same for stayers, but the positive estimate drops for movers. The results in table 8 suggest that product demand is important in estimating a wage offer function.

Before interpreting the maximum-likelihood estimates in table 8, it is important to test whether or not the censoring correction estimates are statistically important. The likelihood ratio test used for each regime is

$$E = -2(L_R - L_U) - \chi^2(K), \qquad (48)$$

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44 This finding is different from Kiefer and Neumann (1979) and Marshall and Zarkin (1987) who report that the variance in reservation wages is larger than the variance of wage offers for both stayers and leavers.

where L_R is the log-likelihood value under the null hypothsis, and L_U is the log-likelihoood value from the maximum-likelihood estimate in table 8. Estimation of the parameters of the likelihood function under the null hypothesis (σ_{1v} = 0 and σ_{2v} = 0, respectively) yields a log-likelihood value of -357.29 for stayers and -50.19 for leavers. The value of the test statistic, E, is 19.24, and 20.028, respectively. This implies that the null hypothesis is rejected at the 0.1% level for both stayer and leavers. It implies that the coefficients estimates by OLS in table 6 definitely suffer from censoring bias. Thus the approach to correct censoring bias is appropriate.

Next, it is important to test the statistical superiority of the model specifications with product demand variables although it is indicated by reasonable t-statistics. Log-likelihood tests are applied for the estimations of both wage offer functions. A log-likelihood value for stayers' wage offer function with product prices (L_U) is -347.67 and a log likelihood value without produc price (L_R) is -388.16. The value of test statistics is 80.98 and the null hypothesis is rejected at 0.1% level. A log-likelihood values for movers with product prices (L_U) is -40.162 and a log likelihood value without produc price (L_R) is -55.149 The value of test statistics is 29.974 and the null hypothesis is rejected at 1% level. The results of tests imply that the model specification that includes the demand variables are statistically superior to the specification without those variables in wage offer equations.

Another interesting issue here is the estimate on the tenure coefficient. Both the coefficient estimates and the t-statistics on the tenure-wage profile and tenuresq are decreased if the demand variables are eliminated from regressions (see table 10). These results are consistent with the argument in chapter III. If the product demand variables are ignored, the error term will exhibit negative correlation which will lead to a downward bias in the tenure coefficient. Thus, the downward bias on the coefficient estimate on the tenure-wage profile exists because of exclusion of demand variables even after censoring-corrected maximum likelihood estimations are applied.

[5] Concluding Remarks

This chapter shows the approach to apply the switching-regime model is appropriate to estimate the efect of job tenure on wage offers. The main point here is to differentiate it from the effect of job tenure on acceptable wages. The critical assumption of this chapter is that the wage contract has one-year duration. If this type of wage contracts is reasonable, the results of this chapter become important.

Another important finding is that the effects of shifts and shocks of product demand on wage offers. A wage offer tends to be higher as industry-specific product demand becomes higher. This effect becomes lower after the correction of consoring or self-selectivity bias. For stayers, a wage offer tends to be lower as product demand has more cyclical fluctuation although the effect is insignificant. For job leavers, a significant positive effect of cyclical fluctuations of product demand on a wage offer is observed.

A model with demand variables has a better specification than a standard model. The downward bias of the estimates on tenure-wage profile is still observed after censoring-corrected maximum likelihood estimations are applied.

Table 5
Means of Principal Variables

variable	All (N=1245)	Stayers (N=1092)	Movers (N=153)
log(wage)	1.2107	1.2310	1.0659
ten83	9.0843	10.7690	4.1961
exp83	18.785	19.446	14.065
school83	12.586	12.558	12.791
married83	0.82490	0.84158	0.70588
white	0.68353	0.67308	0.75817
durable	0.32209	0.31960	0.33987
nondurable	0.21365	0.21978	0.16993
price trend	0.00412	0.00431	0.00277
cyclical	0.05408	0.05532	0.04510
number of dependent in 1983	3.2442	3.2766	3.0131
wife's income if married (dollar)	6177.8	6219.3	5881.2
current industry unemployment rate	9.3316	9.2557	9.8739
current county unemployment rate	8.2112	8.2170	8.1699

log(wage): natural log of real average wage rate of household head.
ten83: year of job tenure in 1983.
exp83: year of full-time job experience in 1983.
school83: year of completed schooling in 1983.
married83 =1 if he is married in 1983.
white = 1 if his race is white.
durable = 1 if his current firm is included in durable manufacturing industries.
nondurable = 1 if his current firm is included in nondurable manufacturing industries.
price trend: estimates on time trend in relative product price regressions in 1984.
Both unemployment rates and wife's income are values in 1983.

Table 6

OLS Estimates

variable	All (N=1245)	Stayer (N=1092)	Movers (N=153)
intercept	-0.26386	-0.18907	-0.93004
	(4.000)	(2.717)	(4.406)
tenure	0.02468	0.02526	
	(6.769)	(5.853)	
tenuresq	-0.00038	-0.00039	
	(3.455)	(3.167)	
exp83	0.01936	0.01789	0.03605
	(5.230)	(4.405)	(3.573)
exp83sq	-0.00033	-0.00031	-0.00060
	(4.295)	(3.734)	(2.549)
school83	0.07750	0.07102	0.11493
	(17.859)	(16.008)	(8.443)
white	0.17165	0.17476	0.14075
	(7.759)	(7.501)	(2.050)
durable	0.13950	0.13402	0.22776
	(5.815)	(5.212)	(3.477)
nondurable	0.04504	0.04725	0.05796
	(1.759)	(1.756)	(0.709)
price trend	3.18848	3.20868	5.41639
	(4.778)	(4.636)	(1.999)
cyclical	-0.02627	-0.12234	0.92788
	(0.262)	(1.158)	(2.883)
unem on price	5.41234	5.31420	7.15511
	(7.928)	(7.282)	(3.476)
R^2	0.439	0.430	0.495

Numbers in parentheses are t-statistics.

tenure: year of job tenure in 1984.
unem on price: estimates on the national unemployment rate in relative product price regressions in 1984.

Table 7

Probit Estimates

variables	Coefficient
constant	0.73615
	(1.691)
tenpre	0.09928
	(4.699)
tenpresq	-0.00180
	(2.518)
exp83	0.01158
	(0.602)
exp83sq	-0.00014
	(0.320)
school83	0.01020
	(0.441)
married83	0.44804
	(3.050)
white	-0.28205
	(2.395)
durable	0.02278
	(0.153)
nondurable	0.11890
	(0.858)
price trend	4.07922
	(2.175)
cyclical	1.26657
	(1.428)
number of dependent in 1983	-0.05612 (1.345)
wife's income if married (dollar)	-0.00001 (1.556)
current industry unemployment rate	-0.02693 (1.701)
current county unemployment rate	-0.01616 (0.788)
Log-Likelihood	-412.00

Numbers in parentheses are t-statistics.
tenpre = tenure at firm of employment as of the 1983 survey plus one, in years.

Table 8

Maximum Likelihood Estimates

variable	Sitter (N=1092)	New Hires (N=153)
intercept	-0.14245	-1.16085
	(1.815)	(5.317)
tenure	0.02238	
	(4.304)	
tenuresq	-0.00034	
	(2.308)	
exp83	0.01764	0.02766
	(4.333)	(2.840)
exp83sq	-0.00031	-0.00058
	(3.751)	(2.442)
school83	0.07069	0.10750
	(16.252)	(8.034)
white	0.18100	0.20825
	(7.376)	(3.023)
durable	0.13551	0.21961
	(4.939)	(3.537)
nondurable	0.04437	0.05081
	(1.647)	(0.624)
price trend	3.08069	4.73928
	(4.040)	(1.880)
cyclical	-0.13285	0.73446
	(1.204)	(2.240)
unem on price	5.23905	6.70866
	(6.779)	(3.503)
r_{1v}	0.30447	
	(1.168)	
r_{2v}		-0.27305
		(2.578)
Log Likelihood	-347.67	-40.162

Asymptotic t statistics in pareteses. r_{12} is an estimate of the residual corretion $[\sigma_{1v}/(\sigma_1\sigma_v)]$ and r_{2v} is an estimate of the residual corretion $[\sigma_{2v}/(\sigma_2\sigma_v)]$.

Table 9

Probit Estimates
Without Product Demand Variables

variables	Coefficient
constant	0.81586
	(1.963)
tenpre	0.10059
	(4.801)
tenpresq	-0.00182
	(2.571)
exp83	0.01181
	(0.616)
exp83sq	0.00015
	(0.349)
school83	0.00797
	(0.351)
married83	0.45635
	(3.124)
white	-0.28043
	(2.402)
number of	-0.06025
dependent in 1983	(1.453)
wife's income if	-0.00001
married (dollar)	(1.588)
current industry	-0.02849
unemployment rate	(2.383)
current county	-0.01340
unemployment rate	(0.659)
Log-Likelihood	-413.71

Numbers in parentheses are t-statistics.

Table 10

Maximum Likelihood Estimates
Without Product Demand Variables

variable	Sitter (N=1092)	New Hires (N=153)
intercept	-0.12100	-1.18425
	(1.636)	(5.217)
tenure	0.02179	
	(4.194)	
tenuresq	-0.00030	
	(2.011)	
exp83	0.01866	0.02866
	(4.468)	(2.740)
exp83sq	-0.00035	-0.00058
	(4.042)	(2.342)
school83	0.06995	0.10750
	(16.229)	(7.734)
white	0.20127	0.23825
	(8.039)	(3.323)
r_{1v}	0.36650	
	(1.792)	
r_{2v}		-0.32305
		(2.578)
Log Likelihood	-388.16	-55.149

Asymptotic t statistics in pareteses. r_{12} is an estimate of the residual corretion $[\sigma_{1v}/(\sigma_1\sigma_v)]$ and r_{2v} is an estimate of the residual corretion $[\sigma_{2v}/(\sigma_2\sigma_v)]$.

Chapter V

Estimation of a Job Separation Function and a Quit Function

[1] Introduction and the Model.

The purpose of this chapter is to estimate a job separation function which includes product demand variables. The statistical technique underlying the estimates is a probit model. Case A in chapter II suggests that the probability of quitting is a decreasing function of a firm's relative product demand and the amount of firm-specific human capital. The main interest here is to test whether an increase in a firm's product price negatively affects job separation (both quits and layoffs). Only those who permanently separated from previous firms are classified in the group of job leavers. Since chapter II provides a theoretical model of quits, this chapter also estimates a quit function by excluding workers who report that they were laid-off by previous employers last year. The main finding of this chapter suggests that a worker tends to leave his current firm as his firm's (industry) product demand becomes lower and has more cyclical fluctuations. Thus quit and layoff rates are decreasing functions of product demand.

Assuming an infinite horizon, the following condition holds when worker i leaves firm j:

$$w_{ij}(t) < [r - A_{ij}(t)]Q = \theta(t) \qquad (49)$$

where $A_{ij}(t)$ is worker i's expected nominal wage growth rate at firm j, Q is the present value of quitting and $\theta(t)$ is the minimum acceptance wage in period t. If $A_{ij}(t) = 0$, we have the standard optimal stopping rule, $w_{ij}(t) = rQ$ (see chapter II for details). Since the r.h.s of (49) is smaller than rQ if $A_{ij}(t) > 0$ is assumed, the imputed income from quitting becomes smaller than a usual model.

The model suggests the following: (a) As industry-specific product demand rises, the probability of quitting drops. (b) As job tenure increases, a worker tends to stay in his present firm. Inequality (49) can be tested empirically since the implications of the model are straightforward. Since the negative relationship between tenure and job separation rates has been found by others (see, for example, Mincer and Jovanovic (1981)), the main interest here is a test of the former.

[2] The Data and Estimation.

The sample size is 1452, 1252 of these stayed in the same firm and 200 permanently separated from the previous firms and found new jobs successfully between the 1983 and the 1984 interview years of the Panel Study of Income Dynamics (PSID). The household head had to meet the same criteria as chapter IV to be included in the sample. The definition of the variables included on the r.h.s of probit equation is the same as the probit equation for stay-or-leave decision in chapter IV (see tables in chapter IV for precise definition of the variables). Trend and a cyclical deviation terms for each industry are calculated by the same manner as previous two chapters.

The estmations of job separation probabilities are shown in table 11.[45]

Table 11 reports significant negative estimates on tenure, which is consistent with the theory of firm-specific human capital and finding of others. Coefficient estimates on full-time work experience and its square value, and the estimates on year of completed schooling are negative but insignificant. However, if tenure and tenuresq terms are droped from the regressors, these estimates become significant. These results are consistent with the results in Mincer and Jovanovic (1981).

Estimates on trends of industry-specific product demand are negative and significant. This implies that a worker tends to stay if his current firm is a growing firm. On the other hand, estimates on cyclical fluctuation of product demand are positive and significant. This implies that a worker tends to leave his current firm as the demand for firm's product becomes more cyclical. These estimates on product demand variables sugget that job separation (quits and layoffs combined) is sensitive to the shifts in product demand, which is consistent with the implication of the derived demand for labor approach. The effect of product demand on job separations has been neglected by micro-labor economists who assume that all firms face the same product demand. The results in this chapter suggest that the effect of product demand is an important

45 Note that regression (1) in the table includes the same independent variables as the probit estimate of stay-or-leave decision in chapter IV.

factor in estimating a job separation equation.

A careful interpretation is necessary concerning the positive coefficient estimates on cyclical fluctuations of product demand. There are two arguments about these results. First, consider quit decisions of workers. Proposition 1 and equation (19) in chapter II imply that the expected wage of a worker rises and he tends to stay as product demand becomes more cyclical. However, as it is mentioned in chapter II, it holds only when workers use expected wage growth rates in their quit decision. In other words, both the actual wage paid and the actual wage growth rate may become lower as product demand has more cyclical fluctuations because of the diffusion term (see equation (5.c) in chapter II). Secondly, these estimations also include the firms' layoff decisions, although the number of layoffs in the sample is smaller than that of quits. (the number of layoffs is 53 and that of quits is 147 in the sample). The theory of permanent and temporary layoffs suggests that the number of permanent layoffs is a decreasing function of (trends in) product demand, and the number of temporary layoffs is an increasing function of cyclical fluctuations of product demand. Furthermore, firms tend to recall laid-off workers if their product demand rises. In other words, the effect of the cyclicality of product demand on permanent job separation is ambiguous. However, as Pissarides (1982) mentions, those laid-off workers may start to look for new jobs. If they find new jobs successfully and move to other firms before they are rehired, they are classified in the group of permanent job separations. If such cases occur, the probability of permanent job separtation rises as cyclical fluctuations of product demand become higher.

Fourth, positive (insignificant) coefficient estimates on county and industry unemployment rates of the previous year suggest that workers tend to leave firms if local labor market conditions are bad. Note that many job changers have moved to a different labor market when they changed jobs since workers are classified into 30 industries. In other words, unemployment rates are considered as indicators to show whether a county and an industry are promising rather than those of showing the easiness to find new jobs. Thus these results make sense intuitively since workers tend to move to promising firms. Fifth, married workers tend to stay in the same firm. Sixth, as wifes' income increase, workers tend to leave previous firm.

Finally, the superiority of the specification of the model including the product demand variables is tested by a log-likelihood test. The test compares regression (1) and (4) in table 11. The value of the test statistic is 9.94, rejecting the null hypothesis at 5% level. Thus a job separation function with demand variables has a better specification.

Table 12 shows the results when the white male sample is used. The results are mostly similar. However, the estimates on trends and cyclical fluctuations of product demand become less significant. This implies that whites' job separation probabilities are less sensitive to shifts and shocks of product demand. These results are consistent with finding in chapter III which reports that whites' wage are less sensitive to industry specific product demand.

[3] Estimation of a Quit Function

Since the theoretical model in chapter II deals with only quits, a quit function is estimated after eliminating laid-off workers from the sample. Let us start with the implication of effects of product demand on quit probabilities. The results show that a worker tends to stay in the same firm as product demand becomes higher and less cyclical fluctuated. However, the coefficients of product demand increases both in absolute magnitude and in significance than in total job separation functions. This implies that quit rates are more sensitive to product demand than layoff rates. This is an interesting finding in this chapter. The estimates on cyclical fluctuations are almost the same as the results in table 11. As product demand becomes more cyclically fluctuated, a woker tends to leave. These results are consistent with the implication of the theoretical model in chapter II, which suggests that a worker's quit decision depends on firms' relative product demand.

Secondly, consider the effects of the human capital variables on quit probabilities. The results are consistent with a standard firm-specific human capital model. Note that table 3 shows that the estimates on job tenure and the square of tenure decrease both in absolute magnitude and in significance than in total job separation functions. It is important to consider an implication of this result. Becker (1962) and Parsons (1972) suggest that the separation of specific human capital into firm-financed and worker-financed component is analytically important, since the former will more directly influence layoff rates and the latter quit rates. The results in table 13 imply that investment in on-the-job training tends to be done by firm-financed manner if years of job tenure really represent investment in firm-specific human capital. In other words, firm-specific human capital is more important in firms' layoff decisions. The results in table 13 support the main implication of the theoretical model in chapter II, which suggests that a worker's quit decision depends on both relative product demand and the amount of firm-specific human capital.

Table 11

Job Separation Estimate (N = 1452)

variables	(1)	(2)	(3)	(4)
constant	-0.66957	-0.22044	-0.51665	-0.56952
	(1.732)	(0.668)	(1.384)	(1.533)
tenpre	-0.11508	-0.11385		-1.23135
	(5.868)	(5.803)		(6.375)
tenpresq	0.00224	0.00220		0.00243
	(3.306)	(3.223)		(3.645)
exp83	-0.01561	-0.01477	-0.05085	-0.01437
	(0.881)	(0.835)	(3.099)	(0.814)
exp83sq	0.00013	0.00010	0.00049	0.00010
	(0.881)	(0.249)	(1.313)	(0.241)
school83	-0.01954	-0.02646	-0.03628	-0.01778
	(0.912)	(1.261)	(1.770)	(0.845)
married83	-0.39616	-0.38765	-0.45801	-0.42015
	(2.974)	(2.920)	(3.529)	(3.175)
white	0.33049	0.31577	0.37943	0.30440
	(3.084)	(2.962)	(3.666)	(2.885)
durable	-0.24513	-0.11593	-0.37277	
	(1.828)	(1.035)	(2.870)	
nondurable	-0.49820	-0.54922	-0.63545	
	(3.015)	(3.327)	(3.972)	
price trend	-10.5577	-11.5642	-11.3047	
	(2.552)	(2.855)	(2.785)	
cyclical	7.06668	9.20960	7.81456	
	(2.308)	(3.217)	(2.634)	
number of	0.03360	0.03521	0.02908	0.03946
dependent in 1983	(0.872)	(0.917)	(0.777)	(1.030)
wife's income if	0.00001	0.00001	0.00001	0.00001
married (dollar)	(1.884)	(1.794)	(1.417)	(1.970)
current industry	0.02826		0.02908	0.02859
unemployment rate	(1.777)		(1.886)	(2.462)
current county	0.02417		0.01970	0.02208
unemployment rate	(1.387)		(1.168)	(1.286)
Log-Likelihood	-496.01	-498.63	-525.50	-502.64

Numbers in parentheses are t-statistics.

Table 12

Job Separation Estimate: White (N=981)

variables	(1)	(2)	(3)
constant	-0.35721	0.17220	-0.37684
	(0.765)	(0.429)	(0.837)
tenpre	-0.12434	-0.12076	-0.13143
	(5.374)	(5.230)	(5.752)
tenpresq	0.00242	0.00232	0.00260
	(3.070)	(2.917)	(3.341)
exp83	-0.00210	0.00299	0.00293
	(0.096)	(0.136)	(0.134)
exp83sq	0.00026	-0.00029	-0.00029
	(0.508)	(0.554)	(0.554)
school83	-0.03444	-0.04283	-0.02789
	(0.508)	(1.761)	(1.145)
married83	-0.45214	-0.44682	-0.04733
	(2.690)	(2.662)	(2.842)
durable	-0.21299	-0.10558	
	(1.362)	(0.805)	
nondurable	-0.55536	-0.60914	
	(2.688)	(2.977)	
price trend	-9.82354	-10.1733	
	(2.033)	(2.135)	
cyclical	7.17573	9.14077	
	(1.962)	(2.694)	
number of	0.03360	0.06094	0.06803
dependent in 1983	(0.872)	(1.216)	(1.366)
wife's income if	0.00001	0.00001	0.00001
married (dollar)	(1.702)	(1.643)	(1.807)
current industry	0.02463		0.02809
unemployment rate	(1.322)		(2.054)
current county	0.03718		0.03521
unemployment rate	(1.855)		(1.785)
Log-Likelihood	-356.09	-358.76	-360.98

Numbers in parentheses are t-statistics.

Table 13

Estimate of a Quit Function (N = 1399)

variables	(1)	(2)	(3)
constant	-1.78530	-1.18479	-1.61966
	(3.615)	(2.806)	(3.449)
tenpre	-0.14361	-0.14131	-0.15266
	(5.492)	(5.392)	(5.972)
tenpresq	0.00293	0.00288	0.00312
	(3.057)	(2.952)	(3.310)
exp83	-0.01182	-0.00948	-0.00978
	(0.493)	(0.397)	(0.414)
exp83sq	-0.00001	-0.00007	-0.00007
	(0.021)	(0.114)	(0.119)
school83	0.02159	0.01539	0.01945
	(0.805)	(0.586)	(0.752)
married83	-0.41317	-0.40279	-0.42235
	(2.474)	(2.422)	(2.566)
white	0.44106	0.40453	0.42596
	(3.146)	(2.921)	(3.104)
durable	-0.51293	-0.42419	
	(2.980)	(2.761)	
nondurable	-0.77697	-0.84546	
	(3.503)	(3.896)	
price trend	-14.8490	-15.8777	
	(2.844)	(3.107)	
cyclical	9.78066	12.4940	
	(3.016)	(3.531)	
number of	0.04965	0.05057	0.05947
dependent in 1983	(1.011)	(1.026)	(1.219)
wife's income if	0.00002	0.00001	0.00002
married (dollar)	(1.949)	(1.826)	(2.140)
current industry	0.02760		0.02517
unemployment rate	(1.257)		(1.725)
current county	0.04553		0.04326
unemployment rate	(2.138)		(2.098)
Log-Likelihood	-314.71	-317.94	-324.06

Numbers in parentheses are t-statistics.

Chapter VI

Estimation of the Job Search Theory

[1] Introduction

This chapter attempts to estimate the expected result of job search. The interest here is what factors will determine whether those who were permanently separated from their previous jobs becomes better off in their new jobs. This chapter, especially, focuses on the effects of product demand on the results of job search in addition to the following standard questions. (1) Whether the type of termination of the previous job (quits or layoffs) affect the results of the job search (whether a laid-off worker usually becomes worse off after the job separation). (2) Whether the method of job search (on-the-job search or full-time search) affects the expected results of the search. Note that not all of those who were involuntarily separated experience unemployment spells since formal and informal prior notification might be given to them. Those who quit may search off-the-job. This chapter assumes that a job is "an experience good"; that is, a worker cannot know the value of a job correctly when he starts a new job. This chapter does not consider those who returned to their previous employers (those who were recalled). They were deleted from the sample. Thus, this chapter is an extension of the work by Gottschalk and Maloney (1985). However, this chapter provides a significant contribution on the estimation of the expected results of job search and derives a different conclusion from theirs.[45]

The following section explain the data and the estimation technique. At first, it explains how product demand variables are created and they are merged with micro-data. Then, the section explains how the effects of product demand on the expected result of search can be estimated. The statistical technique underlying the estimates is a bivariate probit model. Section 3 provides empirical findings, which suggest that product demand is important to determine whether a worker completes his job search process successfully and he becomes better off after changing a job.

[2] The Data and the Estimation

A sample of prime-aged male household heads who were employed at the 1982 interview and interviewed at the 1983 interview of the Panel Study of Income Dynamics (PSID) has drawn. Those who were recalled from their previous employers are deleted from the sample. To be included in the sample the head could not to be self-employed, and had to be between 16 and 60 years old in the 1983 interview year. Furthermore, they had to be employed in the manufacturing,

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45 Their basic conclusions are as follows. The type of termination influences whether a worker becomes better-off or not. The distinction between involuntary termination from a previous job and experience of unemployment is important and the former, not the latter, reduces the probability of becoming become better off. However, their estimation is weak in the sense that they include only dummy variables for the method of search and the type of termination in estimating the probabilty of becoming better off.

transportation, public utilities, wholesale trade, retail trade, and service industries. Among the 1679 workers in this sample, 1250 held the same job in both years, 301 had a different job, and 128 remained unemployed at the 1983 interview date. For the 301 heads, a question regarding whether they were better off in the new job was asked. 246 of the 301 report that they became better off after changing jobs.

The following variables are included in the estimations in addition to the product demand variables that are derived later:

(1) the number of year of job tenure in the previous job;

(2) the age of a household head in the 1983 interview;

(3) the number of years of schooling completed as of the 1983 interview date.

(4) a dummy variable for marital status in the 1983 interview;

(5) a dummy variable for race (whether white or not);

(6) a dummy variable for the method of job search (whether experienced unemployment between the previous job and the new job).

(7) a dummy variable for the type of termination of the previous job (whether laid-off or not).[46]

Those variables are the same as those included in Gottschalk and

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46 Following Gottschalk and Maloney (1985), in the sample a head is classified as being involuntary terminated if he reported either that his previous employer went out of business or he was fired or permanently laid off.

Maloney (1985).[47] Descriptive statistics for the variables in the sample are presented in table 14. It shows that job changers were younger and less likely to be married than stayers. Furthermore, they had below average tenure in their previous jobs.

A difficult problem is how the expected present value of a job can be measured. There is, however, a proxy variable in the PSID. Persons who change jobs are asked a specific question; "on the whole, would you say your present job is better or worse than the one you had before?" Note that some workers report that they were better off even though their money wage rates fell. Thus, the expected present value of new jobs must include nonmonetary aspects of the jobs. Secondly, the sample of people who are asked whether they are better off in their job is not a random sample of the those who left their previous jobs. In order to be asked the question the person must have left the old job and have completed any spell of unemployment undertaken while changing jobs. Thus there is a possibility of selection bias. Thirdly, heads may misreport their evaluation of his old and new job. Although, this variable is not perfect as a proxy for the expected present value of jobs, this is an interesting variable to measure the result of a worker's job search process.

This chapter applies the usual latent variable framework in which there is both a selection equation and a primary equation. The

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47 They use the number of months of previous job tenure instead of years of tenure. However, definitions of other variables are the same as theirs.

selection equation determines whether the person is in the sample of those who left their old jobs and found new jobs. The primary equation determines whether the person is better off. The model is basically the same as Gottschalk and Maloney (1985).[48] The major difference is that the model in this chapter analyzes the effect of the demand variables in addition to the variables that they include. This chapter estimates whether the type of termination is more important than the method of search after controlling product demand in new jobs.

The creation of the demand variables is similar to previous chapters. Price indices from 1969 to 1983 are used as proxy variables for firms' product prices. Producer Price indices are used for manufacturing and consumer price indices for other industries. Then trends and cyclical fluctuations of firms' product demands are calculated by the following time-series regressions:[49]

$$\ln (p_{jt}/CPI_t) = \Phi_{jt} + a_j(TIME) + b_j(UNEMPLOYMENT) + e_j \quad (50)$$

where p_{jt} is the price index of industry j at time t and these variables are both time and industry specific, (TIME) is a time index which starts in 1969 and ends in 1983, and (UNEMPLOYMENT) is

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48 Thus, the correction for selection is analogous to Heckman's famous correction procedure where the primary equation is continuous.

49 Note that the effects of business cycles are eliminated and trends and cyclical fluctuations of industry-specific product demand are calculated.

men's national unemployment rate of twenty-years-old and over. Regressions are run in 40 industries by using 3-digit industry classifications. The sample includes the workers in the manufacturing, transportation, public utility, wholesale trade, retail trade, and service industries. In this chapter retail and wholesale trade industries are added in addition to the industries included in chapter IV in the sample. See appendix 7 for details. Note that those price indices are of the new firms (industry) for job changers (persons who have completed job search process), and for those who were still unemployed at the date of interview, they are those of the industries where heads were looking for new jobs. It is interesting to include product demand variables since product demand conditions of industries will affect the easiness to receive new offers and whether those new offers are attractive. A worker who were looking for a new job in an industry with small job openings might have less chances to complete his job search process successfully than workers who are looking for new jobs in industries with high demand.[50]

A trend of firm j's product demand is given by a_j and its cyclical fluctuation is the standard error of equation (1), σ_j. Both a_j and σ_j are included as proxies of firm j's product demand in the estimation and the effects of product demand on the expected result of the search are estimated. The results can be interpreted as

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50 One problem in the estimation is that rejected job offers cannot be observed. For example, a worker might receive an offer from a growing firm, but accept an offer from a firm with low demand finally, or vice versa.

showing whether product demand of the new firm affects the completion of a worker's job search process and whether job changers become better off because of increases and the fluctuations of their new firms' product demand. Table 1 shows that those who report that they were better off after changing jobs are more likely to be hired in growing industries.[51]

A latent variable Y_1 determines whether the person is in the sample. Assume that Y_1 is a linear function of a vector of human capital variables, the demand variables, and a random error term. If Y_1 exceeds the threshold C_1 a dichotomous variable Y_1^* is set equal to one and the person is included in the sample of having completed the job search process. Similarly, a latent variable Y_2 determines whether or not a worker in the sample becomes better off in his new job. A dummy for whether unemployed or not, a dummy for the type of termination, demand variables and a error term determine whether the dichotomous variable in the primary equation Y_2^* takes on the value of zero or one. Thus, the following equations are considered:

$$Y_1 = X'_1\beta_1 + Z'_1\tau_1 + e_1. \qquad (51)$$

$$Y_2 = X'_2\beta_2 + Z'_2\tau_2 + e_2. \qquad (52)$$

$$Y_1^* = 1 \quad \text{if} \quad Y_1 > C_1.$$

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51 About thirty percent of workers who have left the previous firms in the sample found new jobs or were looking for jobs in the manufacturing.

$= 0$ otherwise

$Y_2^* = 1$ if $Y_2 > C_2$.

$= 0$ otherwise

which yields

$$Pr(Y_1^*=1) = Pr(e_1 > C_1 - X_1\beta_1 - Z'_1\tau_1), \text{ selection equation;}$$

$$Pr(Y_2^*=1) = Pr(e_2 > C_2 - X_2\beta_2 - Z'_2\tau_2), \text{ primary equation.}$$

X'_1 is a vector of human capital variables, X'_2 is a vector of the method of search and the type of termination. Z'_1 and Z'_2 are vectors of product demand, which included trends (a_j) and cyclical fluctuations of product demand. Note that these variables are industry-specific and they are for the firms in the 1983 interview date.

The approach here is to estimate the two equations simultaneously, by assuming that e_1 and e_2 are not independent. That is, the two equations are estimated simultaneouly, using maximum likelihood. The procedure is to estimate bivariate probit equations using the sample of all people who left the old job between two interview dates. The interests here are the effect of involutary job separation, experience of search unemployment spell and the demand variables on the probability to become better off after job separations.

Note that in the estimations, there are problems of selectivity bias since only those who completed job search processs can be observed in the data. There are some unmeasured factors which affect completed search behavior. A worker might complete his unemployment spell because of high expected quality of the job match with a firm or he might complete his search process simply because he set his reservation wage low. The latter case becomes a more serious problem. If he completed his spell for the latter reason, we may oversample workers with low reservation wage who are less likely to become better off after they switched to a new firm. The estimation neglects a prior selection of a worker who decides to change his job. The estimation also does not consider whether a worker quits his former job and whether he was laid off by his former employer (see Gottschalk and Maloney (1985) for details).

Table 15 shows the distribution of workers who change jobs according to the type of termination and whether they experienced unemployment spell between the old and new jobs. A careful examination of table 15 is of interest. Thirty-one percent of job changers report that they were laid-off by the previous employers. Second, not all quitters searched on-the-job and not all laid-off workers experienced unemployment spell between the old and new jobs. About twenty-seven percent of quitters searched full-time, and about nineteen percent of workers who report that they were involuntarily terminated never experienced unemployment. The latter fact implies that significant amounts of formal and informal prior notification were given to those who were laid-off.

Table 16 shows the distribution of workers who report that they were better off after job changes according to the type of termination and whether they experienced unemployment. As expected, about seventy-five percent of people of this group are quitters and about seventy-six percent of them did not experience unemployment spell. However, about twenty-five percent of laid-off workers report that they were better off even though more than sixty percent of them experienced an unemployed spell.

Table 17 shows the distribution of workers who report that they were worse off after job changes according to the type of termination and whether they experienced unemployment. Fifty-eight percent of workers of this group report that they were laid off by the previous employers and about eighty-four percent of them experienced an unemployment spell. Although this number is significantly large, note that not all workers who report that they were worse off experienced an unemployment spell.

[3] Empirical Findings

Table 18 shows the results of two sets of bivariate probit equations to compare the results of Gottschalk and Maloney (1985). The selection equation predicts the probabilty that the head completed his job search process successfully after he left his previous job. Column 1 shows the results of the selection equation of bivariate probit equations whic is estimated over the 429 people who moved. Workers with long job tenure in their previous firms, high education, white, young and the workers who moved to growing firms had a significantly higher probability of having completed their job search process. In other words, they were likely to experience no unemployment spell or have completeed the spell of unemployment by the end of the survey period. However, the marital status and the cyclical fluctuation of the product demand did not affect the probability of having completed their job search process significantly. The interest here is the effects of product demand on the completion of the job search process. The result suggests (1) the workers who were looking for jobs in growing industries had more chances to have completed their job search process, and (2) cyclical fluctuations of product demand have no siginificant effects on the probability.

The primary equation is estimated over the 301 people who completed their jobs successfully and selected by the selection equation. The primary equation predicts the probabilty that a worker became better off at his new job after the head found a new job successfully. There are two results of interest here. The first one is whether the head who experienced an unemployment spell has a lower probability of having become better off. The second one is whether product demand of his new firm affects the probabiluity that he was better off. Column 2 shows the result of the primary equation. It reports that unemployment experience had a significant negative effect on the probabilty of having become better off. As product demand increases, a head is more likely to have been better off. This implies that product demand is an important factor to determine whether a worker became better off after changing a job as well as an experience of an unemployment spell. However, the cyclical fluctuation does not have a significant impact on the probability of having been better off.

The second set of bivariate probit equations attempts to estimate whether experience of unemployment and product demand have significant effects after controlling for the type of termination. Column 3 and 4 report that an experience of unemployment still has a significant impact on the probabilty although the effect is reduced. Concerning the effect of product demand, an increase in product demand still has a significant impact on the probability after controlling for the type of termination. The results suggest (1) unemployment experience is more important than the type of termination in determining whether a head becomes better off,[52] (2) product demand of a new firm has a significant impact on the probability that a head becomes better off, (3) the type of termination marginally affects the probabilty.[53]

Note that (1) and (3) are opposite results from Gottschalk and Maloney (1985). The result of this chapter implies that if a worker experiences an unemployment spell, the probability of successful job search drops. In other words, a worker tends to make his reservation wage lower as unemployment spell increases. This is related to a standard off-the-job search model that says the reservation wage is a decreasing function of unemplyment spell (see Mortensen (1986) and Kiefer and Neumann (1979) for details).

Imprecations (2) and (3) suggest that whether or not a worker

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52 Gottschalk and Maloney (1985) report that unemployment did not have a significant impact after controlling the type of termination.

53 If the demand variables are eliminated from the bivariate probit equations, both the effect of involuntary job separation and an experience of an unemployment spell have significant negative impacts on the probability that a head became better off.

starts a new job in a growing firm is more important than the fact whether he were laid off or not by his previous employer in determining whether he becomes better off after changing a job. These results suggest that the approach used in this chapter is interesting and important in estimating the expected result of a job search process.

Table 14

Means of principal variables in 1983

variable	Full Sample (N=1679)	Stayers (N=1250)	Leavers: Better Off (N=246)	Leavers: Worse off (N=55)
age	38.194	39.734	31.902	31.663
school	12.531	12.480	12.846	12.327
pre tenure			4.918	4.7696
% of married	0.84606	0.87094	0.74086	0.81809
% of white	0.67760	0.67776	0.69767	0.58182
price trend	0.00387	0.00413	0.00315	-0.00509
cyclical	0.05397	0.05394	0.05811	0.05332

school: year of scholling.
pre tenure: year of tenure at previous job.

Table 15

Type of Termination and Method of Search
of All Job Changers (N=301)

		Experienced Unemployment	
Type of Termination	All	Yes	No
Quits	0.691	0.269	0.731
Layoffs	0.309	0.806	0.194
All Types	1.000	0.435	0.565

Table 16

Type of Termination and Method of Search of
Those Who Report Better Off in Their New Jobs (N = 246)

		Experienced Unemployment	
Type of Termination	All	Yes	No
Quits	0.752	0.238	0.762
Layoffs	0.248	0.786	0.214
All Types	1.000	0.374	0.626

Table 17

Type of Termination and Method of Search of
Those Who Report Worse Off in Their New Jobs (N = 55)

		Experienced Unemployment	
Type of Termination	All	Yes	No
Quits	0.418	0.522	0.478
Layoffs	0.581	0.844	0.156
All Types	1.000	0.709	0.291

Table 18

Bivariate Probit Estimates

variable	Pr(Comp)	Pr(Better|Comp)	Pr(Comp)	Pr(Better|Com)
intercept	-0.39520	1.79494	-0.01739	1.97391
	(5.659)	(4.897)	(0.060)	(6.557)
age	-0.01925		-0.01819	
	(2.199)		(1.927)	
pre tenure	0.02657		0.02618	
	(4.558)		(4.444)	
school	0.13062		0.12815	
	(5.412)		(4.503)	
white	0.13983		0.16490	
	(3.191)		(3.183)	
married	0.05091		0.01923	
	(0.299)		(0.399)	
price trend	1.54091	1.80720	1.58678	1.76549
	(2.591)	(2.236)	(2.234)	(2.052)
cyclical	0.17162	1.46130	0.14537	1.34270
	(1.019)	(0.754)	(1.438)	(0.645)
layoff			-0.16876	-0.35549
			(1.026)	(1.736)
unemployed		-0.81108		-0.60551
		(4.746)		(2.736)
Rho	-0.47651		-0.52724	
	(1.490)		(1.715)	
Log Likelihood	-741.82		-740.45	

Numbers in parentheses are t-statistics.

(Appendix 1): (Ito Stochastic Differential Equation)

In general, an Ito stochastic differential equation is interpreted as follows. Let X(t) satisfy the following Ito stochastic differential equation:

$$dX(t) = a[X(t),t]dt + b[X(t),t]dz(t) \qquad \text{(A1)}$$

with initial condition $X(0) = X_0$. Here we can interpret a[X(t),t] as a "drift" or "trend" term, and b[X(t),t] as "diffusion" term. z(t) is a standard Weiner process and X(t) is a Markov process with instantaneous mean a[•] and instantaneous variance $\{b[\cdot]\}^2$. If a[•] = 0, we call a driftless Wiener process. If b[•] = 0, (A1) is reduced to a deterministic differential equation. Transforming the above equation into an integral equation, it follows

$$X(t) = X(0) + \int_0^t a(s,X(s))ds + \int_0^t b(s,X(s))dz(t) \qquad \text{(A1')}$$

Note that X(0) is a random variable, the first integral in the right-hand side of (*) can be understood as a Riemann integral, and the second integral is an Ito intergral.

(Appendix 2): (Ito's lemma)

Let $u(t,X)$: $[0,T] \times R \to R$ be a continuous nonrandom function with continuous partial derivatives u_t, u_X and u_{XX}. Suppose that $X(t) = X(t,w)$:$[0,T] \times \Omega \to R$ is a process with stochastic differential (A1). Let $y(t) = u(t,X(t))$. Then the process y(t) has also a differential on [0,T] given by

$$dy(t) = [u_t(t,X(t)) + u_X(t,X(t))f(t)$$

$$+ (1/2)u_{XX}(t,X(t))\delta^2(t)]dt + u_X(t.X(t))\delta(t)dz(t). \quad (A.2)$$

In the text it is assumeed that $y(t) = u(t,p,x) = w(t) = px$, where p is the product price and x is the real wage. Thus $u_{xx} = u_{pp} = u_t = 0$.

(Appendix 3):

It is interesting to consider the meaning of the wage equation (5.a) with the initial wage offer (5.b). For this purpose, consider a discrete version of the Ito stochastic differential obtained by taking a mesh of points t_i, which are considered as worker i's tenure at firm j starting at time period t(0) (as illustrated in Figure 3) such that

$$t(0) < t(1) < t(2) < \cdots < t(n-1) < t(n) = t \quad (A.3)$$

and writing the equation as

$$w_{ij}(m+1) = w_{ij}(m) + Aw_{ij}(m)\Delta t(m) + Bw_{ij}(m)\Delta z(m), \quad (A.4)$$

where $w_{ij}(m) = w_{ij}(t(m))$, $\Delta t(m) = t(m+1) - t(m)$, and $\Delta z(m) = z(m+1) - z(m)$. From equation (A.4), an approximate procedure for solving the equation is to calculate $w_{ij}(m+1)$ from the knowledge of $w_{ij}(m)$ by adding a deterministic term, $A(m)w_{ij}(m)\Delta t(m)$, and a stochastic term, $B(m)w_{ij}(m)\Delta z(m)$. The stochastic term contains an element $\Delta z(m)$, which is the increment of the Wiener process, but is statistically independent of $w_{ij}(m)$. The solution is then formally constructed by substructing $w_{ij}(m)$ from both sides and dividing by $w_{ij}(m)$ on both sides.

$$\frac{w_{ij}(m+1) - w_{ij}(m)}{w_{ij}(m)} = A(m)\Delta t(m) + B(m)\Delta z(m).$$

By letting the mesh size go to zero, that is, by letting $\Delta t(m) = t(m+1) - t(m) = dt$ and $\Delta z(m) = z(m+1) - z(m) = dz$, and by approximating the left hand side by $d\ln w_{ij}$, we get $d\ln w_{ij} = Adt + Bdz$, which is the same as equation (5.a) with initial condition (5.b). See Figure 3. Note that the realized value of $\ln w_{ij}(m+1)$ may be smaller ln $w_{ij}(m)$ even if A(m) is positive (find that $\ln w_{ij}(3)$ is smaller than $\ln w_{ij}(2)$ even though A(2) is positive in figure 3).

(Appendix 4): (The Differential Chapman-Kolmogorov Forwad Equation)

Consider the following three conditions for all $e > 0$:

$$\text{(a)} \lim_{t\to s} \frac{1}{t-s} P(y,t|x,s)dy = W(y,t).$$

uniformly in x, y, and t, s for $|y - x| \geq e$:

$$\text{(b)} \lim_{t\to s} \frac{1}{t-s} \int_{|y-x|<e} (y-x)P(y,t|x,s)dy = A(x,s) + o(e):$$

$$\text{(c)} \lim_{t\to s} \frac{1}{t-s} \int_{|y-x|<e} (y-x)^2 P(y,t|x,s) = B(y,t) + o(e):$$

the last two being uniform in x, e, and s.

Note that all higher-order coefficients of the form in (b) and (c) must vanish. W(y,t), A(y,t) and B(y,t) are called the jump coefficient, the drift coefficient, and the diffusion coefficient, respectively.

The differential Chapman-Kolmogorov forward equation is given by as follows;

$$\frac{\delta P(y,t|x,s)}{\delta t} = - A(y,t) \frac{\delta P(y,t|x,s)}{\delta y} + B(y,t) \frac{1}{2} \frac{\delta^2 P(y,t|x,s)}{\delta^2 y}$$

$$+ \int [W(y|u,t)P(u,t|x,t) - W(u|y,t)P(y,t|x,s)] \, du. \qquad \text{(C.K)}$$

If W(y,s) = 0, then the sample path of x(t) becomes continuous and such process is called as a diffusion process (no jump in the sample path). Equation (5.a) is an example of the diffusion process.

(Appendix 5): (Industry Classifications in Chapter III)

a) 2-digit industry classifications in the sample:

1) metal; 2) machinary, including electrical; 3) motor vehicles and other transportation equipment; 4) other durable manufacturing industries; 5) food and kindred products; 6) textile mill product, apparel and other fabricated textile products; 7) chapter and allied products; 8) chemical and allied products; 9) other nondurable manufacturing industries; 10) transportation; 11) public utilities; 12) personal services; 13) amusement and related services;

14) medical and health services; 15) educational services.

b) 3-digit industry classifications in the sample:

1) lumber and wood products; 2) furniture and household durables; 3) metal; 4) fabricated metal; 5) machinary, except electrical; 6) electrical machinary; 7) automobiles; 8) transportation equipment; 9) photographic equipment; 10) mischellaneous product; 11) food and kindred products; 12) textile mill product; 13) apparel and other fabricated textile products; 14) chapter and allied products; 15) chemical and allied products; 16) petroleum and coal product; 17) rubber and plastic products; 18) other nondurable manufacturing industries; 19) transportation; 20) electric light and power; 21) electric-gas utitlities; 22) gas supply system; 23) other utility services; 24) personal services; 25) amusement and related services; 26) professional medical services; 27) medical care services; 28) schools; 29) educational services; 30) other professional services.

(Appendix 6): (3-digit industry classifications in Chapter IV)

1) lumber and wood products; 2) furniture and household durables; 3) metal; 4) fabricated metal; 5) machinary, except electrical; 6) electrical machinary; 7) automobiles; 8) transportation equipment; 9) photographic equipment; 10) mischellaneous product; 11) food and kindred products; 12) textile mill product; 13) apparel and other fabricated textile products; 14) chapter and allied products; 15) chemical and allied products; 16) petroleum and coal product;

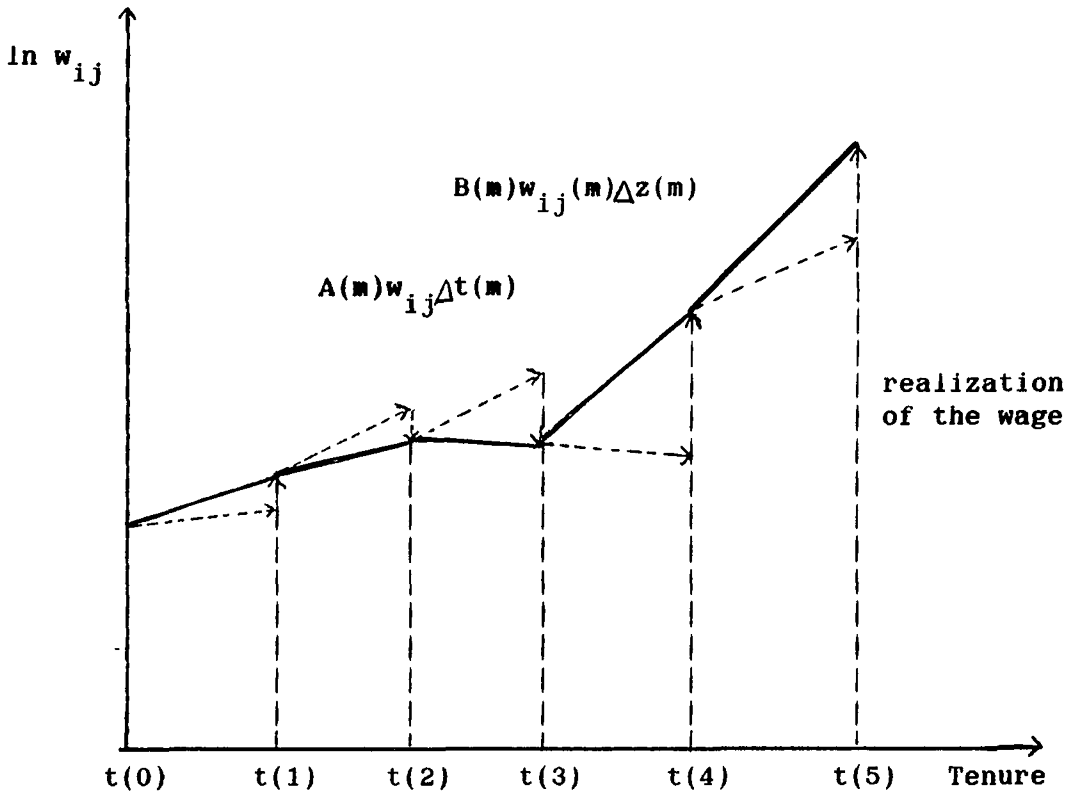
17) rubber and plastic products; 18) other nondurable manufacturing industries; 19) transportation; 20) electric light and power; 21) electric-gas utitlities; 22) other utility services; 23) business and repair services; 24) personal services; 25) amusement and related services; 26) professional medical services; 27) medical care services; 28) schools; 29) educational services; 30) other professional services.

(Appendix 7): (3-digit industry classifications in Chapter VI)

1) lumber and wood products; 2) furniture and household durables; 3) metal; 4) fabricated metal; 5) machinary, except electrical; 6) electrical machinary; 7) automobiles; 8) transportation equipment; 9) photographic equipment; 10) mischellaneous product; 11) food and kindred products; 12) textile mill product; 13) apparel and other fabricated textile products; 14) chapter and allied products; 15) chemical and allied products; 16) petroleum and coal product; 17) rubber and plastic products; 18) other nondurable manufacturing industries; 19) transportation; 20) electric light and power; 21) electric-gas utitlities; 22) other utility services; 23) retail trade of food and farm products; 24) retail trade of durables; 25) retail trade of nondurables; 26) other retail trade; 27) wholesale trade of food and farm products; 28) wholesale trade of durables; 29) wholesale trade of nondurables; 30) other wholesale trade; 31) business service; 32) repair services; 33) professional personal services; 34) other personal service; 35) amusement and related services; 36) professional medical services; 37) medical care serv-

ices; 38) schools; 39) educational services; 40) other professional services.

Figure 3


ln w_{ij}
B(m)w_{ij}(m)Δz(m)
A(m)$w_{ij}\Delta$t(m)
realization
of the wage
t(0)
t(1)
t(2)
t(3)
t(4)
t(5)
Tenure

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