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JOB SEARCH AND LABOR MARKET ANALYSIS

by

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I. An Introduction

The theory of search is an important young actor on the stage of economic analysis. It plays a major part in a dramatic new field, the economics of information and uncertainty. By exploiting its sequential statistical decision theoretic origins, search theory has found success by specializing in the portrayal of a decision maker who must acquire and use information to take rational action in an ever changing and uncertain environment. Although its specific characterizations can now be found in many arenas of applied economic analysis, most of the theory's original roles are found in the labor economics literature. The purpose of this essay is to review its performances to date in labor market analysis.

That the theory's services have found useful employment is not particularly surprising. Actors that portray only self seeking workers in certain and static environments cannot represent many of life's real work experiences. The time workers spend unemployed, movements from job to job during the work life, and the allocation of the working life between market work and alternative activities in a dynamic environment are all left inadequately characterized in dramas that feature such actors. Although it is too soon for either an "Oscar" or knighthood, the talents of job search theory for the consistent portrayal of the dynamic dimensions of worker experience can be demonstrated. Furthermore, methods for empirically testing the theory's adequacy as a principal in future plays with these plots are becoming discernable as a consequence of this consistency. These serve as the two principal themes of this review.

The classic income-leisure choice model continues to enjoy a very successful run as a tool for formulating the decision to seek employment. Its extensions to the analysis of investment in education and training, retirement, the labor force participation of married women, taxes on labor income, and the decision to have and invest in children have greatly enriched the collection of hypotheses concerning household behavior. The theory of job search has developed as a complement to the older theoretical framework. Many writers found that the classic labor supply model with its emphasis on unilateral and fully informed choice could not explain important features of the typical individual's experience in the labor market. The experience of unemployment is an important example. Within the income-leisure choice framework, unemployment simply has no interpretation as a consequence of the assumptions that jobs are instantaneously available at market clearing wage rates known to the worker.

The profession's view of both the employment and non-employment experiences of individual workers changed dramatically in the late 60's and early 70's as a consequence of studies of flows in and out of employment at the firm level, of propensities of workers to leave unemployment in cross section data, and of the labor market experience of individual workers over time found in various panel data sources. In a given population of labor force participants, the steady state fraction who are unemployed is equal to the product of the average frequency and duration of unemployment spells. These data sources revealed that unemployment spells are typically frequent but short in all phases of the business cycle although counter cyclic increases in both frequency and duration contribute to the well known time series behavior of unemployment rates. Furthermore, differences in unemployment and participation rates across different demographic groups reflect differences in durations and frequencies of unemployment and participation spells. These empirical contributions suggested the idea of viewing a worker's labor market history as the realization of a stochastic process. This view contributed significantly to the development of the search theoretic approaches to the analysis of unemployment durations, job turnover, and individual labor market experience reviewed in section II of this essay.

The search theoretic approach to the analysis of unemployment spell durations was the original contribution of search theory to labor market analysis. The presentation of the original formal wage search model and its empirical implications are the topics of section II of this paper. This model, which is derivative of developments in the theory of sequential statistical decision theory, is designed to focus on the typical worker's problem of finding employment in a decentralized labor market. Information regarding the location of vacant jobs and the compensation that they offer is recognized as imperfect. This information must be acquired and evaluated before a worker can or is willing to become employed. Viewing this process as costly and sequential provides a framework for the analysis of observed variation in the unemployment spells that individual workers experience and in the wages received once employed. Formally, the length of time a worker spends unemployed and the subsequent wage received once employed are both random variables with distributions that depend on the worker's characteristics and those of the environment both directly and indirectly through the worker's determination of conditions for acceptable employment. Because the framework has implications for the distribution of observables, econometric methods for estimation and testing are suggested by the theory.

Section III of the essay reviews more recent theoretical extensions of the search theoretic approach designed for the analysis of job turnover behavior, wage growth, and other dynamic features of an individual's labor market experience.

As a consequence of search costs and time discounting, no rational worker waits indefinitely for an opportunity to be employed in the best of all jobs that might be available. Hence, even employed workers have incentives to continue the search for a better employment opportunity. The first topic considered in Section III is an extension of the standard wage search model to search on the job at effort levels that are endogenously determined. This form of the model provides an explanation for the observed negative association between the propensity to separate from a job and the wage earned on a job, holding earnings ability constant. Furthermore, the theory suggests that productivity growth attributable to the acquisition of human capital need not be required as an explanation for positively sloped wage-experience profiles. Although this explanation is now generally acknowledged in the literature on turnover and wage dynamics, its relative importance as an explanation for individual wage growth is still an open question.

Many relevant characteristics of a job-worker match cannot be observed without error but must be experienced. These experiences as they occur provide information about the expected future quality of a specific job-worker match relative to the set of alternatives. This information is useful in the decision to continue the match. This process of learning about jobs and occupations as a means of finding a satisfactory place in the work world has long been thought an important explanation for high turnover rates among young workers. The second topic of Section III is a review of the first formal models of learning on the job about the quality of the match. The model considered in detail is another version of the general sequential search model. It implies the wages earned by those who stay on a job increases with tenure even when productivity and tenure are unrelated. Although these implications are broadly consistent with empirical observations, particularly in the most relevant case of young workers, only recently has the stochastic structure of the model been applied in econometric work in a manner that permits the testing of the quantitative importance of the theory.

Longitudinal observations on the labor force histories of individual workers reveal that varied patterns of sequences of spells of employment in different jobs, spells of unemployment, and spells of non-participation characterize worker labor market experience. Empirical attempts to isolate the differences in the frequencies, durations, and patterns of such spell sequences experienced by workers with different demographic characteristics have been based, either explicitly or implicitly, on the assumption that an individual's spell history can be modelled as a Markov chain. Recently, theoretical models based on Markov decision theory have been developed that permit a more "structural" interpretation of these histories. In these models, movements among jobs and labor force states are viewed as the consequence of actions taken by the worker in response to stochastic changes in a worker's opportunity to work, the wage given such an opportunity, and the alternative value of time spent in non-work activities. A brief introduction to this type of modelling is the final topic considered in Section III. Although the development of this approach is in its infancy, the method promises new insights into how the dynamic processes influencing an individual's opportunities at any point in time and the individual's responses to the realizations of these processes determine the observed distribution of earnings and the distribution of workers over participation categories.

Answers to two purely theoretical questions raised by the sequential search approach to the problem of finding acceptable employment, more generally the problem of "shopping", are reviewed in Section IV of the paper. First, is a distribution of price offers for an identical good sustainable when agents on one side of the market act as price setters while agents on the other side are searching price takers? Second, is the level of unemployment that necessarily arises as a consequence of the time required to find employment, more generally the level of the stock that acts as a buffer between the decision to transact and the actualization of the exchange, socially efficient? Although affirmative answers to both questions have been constructed, "no" seems to be the more reasonable theoretical answer to both.

A brief word on the approach taken in this review is in order. Although the references include a reasonably comprehensive list of works on the theory of search and its applications in labor economics, the paper is not intended to be an exhaustive survey of individual contributions. Instead, the presentation is constructed with two goals in mind. First, the theoretical formulations that have been or are most likely to be applied in empirical studies are emphasized. Second, these models are presented in a manner that illustrates their common formal structure. The hope is that this form of presentation will communicate the unity of the theoretical ideas, on the one hand, and the potential usefulness of that unity for the purpose of empirical estimation and testing, on the other.

II. The Wage Search Model

That the typical worker has a variety of earnings opportunities available but has to shop to find the "best" one is the principal observation that motivated the original formulation of search models and continues to motivate the development of search theory. The worker's decision problem under these conditions involves a choice of a strategy for "shopping" and the selection of a criterion that determines when an offered wage is "acceptable." Stigler's [1961, 1962] original formulation of the worker's decision was as an optimal sample size problem. He views the worker as selecting a random wage sample of size n at a cost of c per wage sampled. The worker accepts employment at the firm offering the highest wage in the sample. The worker's problem is to choose the size of the sample. This formulation has a certain appeal in that one can imagine n to be the number of applications filed with prospective employers. Furthermore, the perfect information case corresponds to a sampling cost of zero. In this case, each worker would sample the entire wage population and go to work for the employer offering the highest wage rate.

Subsequent theoretical analyses of the job search problem are based on the sequential "stopping" approach borrowed from statistical decision theory.[1] In these formulations, the worker is viewed as sampling wage offers one at a time and deciding on the basis of the sample obtained to date whether or not to stop the search or to continue. This procedure generally dominates the fixed sample size strategy in the sense that its maximal expected present value of future income is higher. In addition, the approach has the advantage of allowing for numerous realistic complications; e.g., that "shopping" takes place in real time, that offers must be accepted shortly after they are made, and that learning about the nature of the true distribution of offers may be an important part of the shopping process, etc. Of course, when a sequential strategy is used, the realized sample size is a random variable whose distribution is determined in part by the nature of the "stopping rule." Hence, in real time, the random sample size may be interpreted as a distribution of lengths of the random search spell. The implications of this interpretation of the theory for the distribution of search spell lengths have proven to be important in attempts to empirically estimate search models and to apply them to policy related issues. Early examples of applications of the sequential sampling approach that exploit these features include Gronau [1971], McCall [1970], and Mortensen [1970].

This section of the essay has three parts. In the first, the so-called "standard" or "original" model of sequential wage search is presented. The second is devoted to an exposition of its implications, particularly for the probability distribution over completed spells of unemployment. The third and final section introduces applications of the model and the problems encountered in recent attempts to empirically estimate its parameters and test its implications.

A. Wage Search in "Real" Time

If economics can be defined as the study of the allocation of scarce resources, then the central focus of labor economics is the investigation of the way that time endowments of individual human beings are spent. Shopping is one of the numerous activities that tend to absorb time. Little quantitative information is available about the costs and the technology of shopping other than impressions based on personal experience. However, given the fact that the labor market itself accounts for more than two-thirds of household income, one would not be surprised that the time spent shopping in that market is of significant importance and value what ever may be its quantitative magnitude and economic efficiency.

The purpose of this section is to illustrate how contributors to the literature on shopping in the labor market have adapted the statistical theory of optimal stopping to the problem of finding a job paying the "best" wage taking the costs of finding that wage into account. The focus here is not only on the micro economics of job search. The intention is to develop a theoretical foundation which is strong enough to support an understanding of subsequent applications of the theory to a variety of substantive issues of interest to labor economists and subsequent contributions to the theory of equilibrium wage dispersion and unemployment. The foundation stones underlying this structure are the dual suppositions that search for any job, let alone a better one, requires time and resources and that the returns to this investment in search are uncertain and in the future.

Lags in the process by which information is transferred from prospective employer to willing employee are everywhere. Of course, there are many channels of information transfer. One often thinks of workers trudging from personal office to union hiring hall looking for an employment opportunity when the term "job search" is used. Yet, a casual conversation with a friend or relative over a beer is a surprisingly common method of finding a job. Obviously, other methods include reading the want ads, which we are told are always there even in the midst of even the worst recession, registering at the public employment office, and hiring the services of a private employment agency. Still, whatever the method used, the interested worker must devote time and money to the search activity which could otherwise be allocated elsewhere and the investment has an uncertain and variable future payoff.[2]

In order to take appropriate account of the fact that search requires time and that the consequences of that search are uncertain, the classic optimal stopping problem must be adapted and generalized in several respects. First, the cost of search should be interpreted as a flow per unit search time, a net deduction from the value of the time which could otherwise be spent in some other activity, plus out-of-pocket financial costs. Second, one must recognize that job availability is as important as search effort in determining the time required to locate a job.[3] Finally, the costs and returns attributable to future search activities need to be discounted.

Although these additions have little mathematical significance, they do enrich the stopping model considerably.

When search takes place in real time, it is time spent rather than the number of wage rates sampled that is the focus of the analysis. Initially, let time be represented by a sequence of discrete periods of variable length h. Let b denote the value of the time that could be spent in some other activity per unit time. Finally, let $\beta(h)$ represent the discount factor applied to future costs and benefits incurred per period of length h. To account for both job availability and the uncertainities inherent in the job search process, we introduce $q(n,h)$ as a probability distribution over the number of offers received per period of length h spent searching. Let the c.d.f. $F(w)$ represent the distribution of the wage offers. Any offer received is viewed as a random sample from this distribution. It is important to point out that both the distribution of the number of offers received per period and the wage offer distribution are assumed to be unchanging over time and known to the worker.[4] In addition, the analysis is restricted to the case of no recall of offers received in previous periods, mainly for the purpose of simplifying the exposition, although the worker is able to choose among the offers received within the period. Of course, the results reviewed can usually be generalized to the case of recall, when they in fact differ, by simply regarding the "wage" currently considered as the highest of those previously seen and still available.[5]

The sequence of future best wage offers is i.i.d. by assumption. The best offer of the n received in any period of length h can be specified as follows:

$$(2.1) \qquad w = \max[w_1, \ldots, w_n]$$

where the distribution of w_i is $F(\cdot)$ for all $i = 1,2,\ldots n$.

An important point to note here is that the receipt of no wage offer, $n = 0$, during the period is a possibility.

Let $G(w,n)$ represent the probability that the best of n offer is less than or equal to w given that $n \geq 1$. It is the distribution that is induced by (2.1) and the assumption that each of the n wage offers received during a period of length h is an independent random draw from $F(\cdot)$. Let $q(n,h)$, $n = 0,1,\ldots$, represent the probability that the worker will receive n offers during a period of length h. The purpose of introducing this concept is to allow for job availability. Because it imposes the restriction that time is required to find a job and that job opportunities are found sequentially, a natural specification for this distribution is the Poisson,

$$(2.2) \qquad q(n,h) = e^{-\lambda h}(\lambda h)^n/n!,$$

where λ denotes the offer arrival rate and its inverse is the expected length of time between offer arrivals. The crucial assumption underlying (2.2) is that the instantaneous probability of the next arrival is independent of the length of time since the last. This assumption would seem to be as appropriate in the job search context as it has been proven to be in so many other applications.

The mathematical decision framework within which both the optimal stopping and the wage search problem are set is the theory of dynamic programming. Essentially the "trick" of the theory is Bellman's [1957] principle of dynamic optimality. Stated in words, the principle asserts that the present decision in a sequence of decisions maximizes current net return plus the expected future stream of returns, appropriately discounted, under the presumption that decisions in the future are made optimally where the expectation taken is conditional on current information. In short, a multi-stage decision problem is converted by the principle into a sequence of single stage decision problems. Appropriate conditions for application of the principal require that the decisionmakers preferences over the future can be regarded as the discounted sum of returns accruing over the future. Bellman's principle is applied liberally throughout this essay.

Although the stream of future returns can be interpreted as Von Neumann and Morgenstern "utilities", in most of the wage search literature they are taken to be net incomes and the discount rate is called the interest rate.[6] Hence, the worker is regarded, at least implicitly, as risk neutral and not constrained in the capital market. Typically the worker is also assumed to live forever, i.e., the decision horizon is infinite. Obviously, all three of these assumptions are absolutely ridiculous in the context of an unemployed worker seeking an employment opportunity. Nevertheless, they have been maintained in the literature because doing so permits a relatively simple means of gaining insight into the essentials of the problem. We follow the literature's dictates here.

Let W(w) represent the given present value of stopping, accepting the best offer received, w, during any period and working forever after at that wage. The function is continuous, and strictly increasing, and such that W(0) = 0 by assumption. Let V( ) denote the value of searching during the next period given the worker's information, . It is the expected present value of future net income given that the optimal strategy will be pursued in the future conditional on the worker's current information. In order to maximize wealth, the worker continues to search while unemployed given an available best wage offer w if and only if $V(\Omega) > W(w)$. Since the analogous acceptance rule applies to the next period,

$$(2.3) \qquad V(\Omega) = (b-c)h + \beta(h)E\{\max[V(\Omega(t+h)),W(x)] \mid \Omega(t) = \Omega\}$$

where x is the random best offer realized during the next period of length h and $\Omega(t+h)$ is the information, possibly a random variable, that the worker will have in the next period. The first term on the right side of (2.3) is the difference between the value of time spent as "leisure" less the value of time and out of pocket costs spent searching a period of length h. The second term is the expected present value of tomorrow's optimal stopping decision made once the next period's best offer and information is known conditional on the information available today.

Given the assumption that the future sequence of best offers is i.i.d. and the assumption that the distribution for each period is known, the worker learns nothing over time, i.e., $\Omega(t) = \Omega(t+h)$. Consequently, the value of continued search is a constant through time, denoted as V. By virtue of equations (2.1) - (2.3), V solves

$$V = (b-c)h + \beta(h)[\sum_{1}^{\infty} q(n,h) \int_{0}^{\infty} \max[V,W(x)]dG(x,n) + q(0,h)V]$$

or equivalently,

$$(2.4) \qquad (1-\beta(h))V = (b-c)h + \beta(h)[\sum_{1}^{\infty} q(n,h) \int_{0}^{\infty} \max[0,W(x) - V]dG(x,n)].$$

Since (2.4) has a unique solution for the value of search, V, provided that the mean of the wage offer distribution is finite, the worker's optimal search strategy satisfies the reservation property and the reservation wage, w^*, is the unique solution to

(2.5) $W(w^*) = V.$

By the <u>reservation property</u>, we mean that the worker's expected wealth maximizing stopping strategy has the property that it is optimal to accept employment (stop searching) when the highest offered wage in any period is equal to or in excess of a critical number called the reservation wage, which in this case is w^*. The fact that $W(w) > V$ for all such wage rates and Bellman's principle imply that the optimal strategy has the property in this particular case.

Given the definition of best offer in (2.1) and the Poisson offer arrival specification in (2.2), equation (2.4) simplifies considerably in the continuous time version of the analysis which corresponds to the limiting case of an infinitesimal period length. Specifically, (2.2) implies that the probability of a single offer arrival per period of length h is approximately equal to λh while the probability of more than one arrival is approximately zero when the length of the period is small. Formally,

$$\lim_{h\to 0} q(1,h)/h = \lambda \text{ and } \lim_{h\to 0} q(n,h)/h = 0 \text{ for } n > 1.$$

In addition, the discount factor is

$$\beta(h) = e^{-rh} \text{ so that } \lim_{h\to 0}[1-\beta(h)]/h = r$$

where r represents the interest rate. Hence, by dividing both sides of (2.4) by h and taking the limit of the results as $h\to 0$, one obtains the following continuous time analogue:

$$(2.6)\qquad rV = b-c + \lambda\int_0^\infty \max[0,W(x)-V]dF(x).$$

Since V represents the worker's "wealth" when searching, rV is the imputed "income" derived from that wealth per unit time period. Equation (2.6) asserts that it is equal to the difference between the value of time spent not working and the cost of search plus the expected rate of capital gain attributable to search, the product of the instantaneous offer arrival rate and the expected difference, when positive, between the wealth associated with employment and that imputed to search. Since the present value of a future earning stream given a wage equal to x is $W(x) = x/r$, the reservation wage is equal to imputed search income,

$$(2.7)\qquad rV = rW(w^*) = w^*,$$

by virtue of equation (2.5).

To recover the fundamental reservation wage equation for this model, simply use (2.7) to eliminate V is (2.6) and let $W(x) = x/r$. The result is

$$(2.8)\qquad (\lambda/r)\int_{w^*}^\infty [x-w^*]dF(x) = c + w^*-b.$$

The left side is interpretable as the marginal return to continued search given an offer equal to the reservation wage, the present value of the expected capital gain attributable to finding an acceptable offer next period with due account taken of the frequency with which offers arrive. The right side, which is the cost of search this period when the reservation wage is offered, is composed of two parts. The first is the out-of-pocket cost while the second is an opportunity cost term equal to the difference between the value of working at the reservation wage and the value of "leisure".

Notice that (2.8) suggests the possibility $w^* < b$, that the job an unemployed worker is willing to accept pays less than the value of "leisure". This possibility seems and is inconsistent with a rational participation decision on the worker's part. Indeed, were the worker not to participate, his "wealth" would be b/r, the present value of an infinitely long life spent in leisure. In order to induce him to participate as an unemployed searching worker the value of search V must be at least as large. Taking this participation condition into account, we find that equations (2.5) - (2.8) imply

$$(2.9) \qquad rV = w^* > b \text{ if and only if } (\lambda/r) \int_b^\infty [x-b]dF(x) > c$$

In other words, a worker is a willing participant in the labor market, equivalently the reservation wage is at least as large as the value of leisure, if and only if the return to search, given a reservation wage equal to the value of leisure is at least as large as the out of pocket cost of search.

The idea that the reservation wage might be different from the value of leisure in the face of time and money costs of job search was well established in the literature before formal derivations of the type just presented appeared. However, it was thought that the reservation wage of unemployed workers should fall over time. In a classic and influential article, Kasper [1967] reported empirical evidence in support of this hypothesis. Among the original formalizations of the reservation wage theory, Gronau [1971] demonstrated that the stopping model has such an implication when a finite work life is assumed simply because the return to search, like the return to any other investment in human capital, falls as a worker's retirement date is approached. However, this is an aging effect, not a search tenure effect. Given the relatively short duration of unemployment spells and any reasonable interest rate, one can easily show that the aging effect fails to explain the relatively large rates of decline in the reservation wage that Kasper and others since have reported for relatively young workers. In sum, except for those very near retirement age, the infinite working life abstraction is not a problem.

Still the constant reservation wage result is inconsistent with reported empirical fact. An alternative and I feel more convincing explanation for a declining reservation wage is the likely possibility that most unemployed workers are liquidity constrained. The well known inability of unemployed workers to borrow money in the official credit market supports this contention. The simplest way to formally incorporate a liquidity constraint into the simple model is to assume that the worker can self-finance the out-of-pocket cost of search only for a finite time period of length T. Specifically, the funds available for the purpose of seeking a job equal cT. In this case, the value of search will depend on time left until the liquidity barrier is binding which will be denoted as $\tau = T-t$, where t is the length of the unemployment spell to date. Since the index τ reverses the order of time, the value of searching one more period given that there are τ periods left is given by the following recursive analogue of equation (2.3):

$$V(\tau)-V(\tau-h) + (1-\beta(h))V(\tau-h) = (b-c)h$$
$$+ \beta(h)[\sum_{1}^{\infty} q(n,h) \int_{0}^{\infty} \max[0,W(x)-V(\tau-h)]dG(x,n)].$$

By dividing both sides by h and taking limits as $h \to 0$, one obtains the differential equation

$$(2.10) \qquad dV(\tau)/d\tau = \lambda \int_0^\infty \max\ [0, W(x) - V(\tau)]dF(x) + b - c - rV(\tau).$$

Since the workers only alternative when the liquidity constraint is binding is to drop out of the labor force,

$$(2.11) \qquad V(0) = W(b) = b/r.$$

The reservation wage given τ period remaining $w(\tau)$, solves

$$(2.12) \qquad V(\tau) = W(w(\tau)) = w(\tau)/r.$$

Consequently, equations (2.10) (2.11), and (2.12) imply

$$(2.13a) \quad dw(\tau)/d\tau = r[w^* - w(\tau)] + \lambda \int_{w(\tau)}^\infty [x - w(\tau)]dF(x) - \lambda_* \int_{w^*}^\infty [x - w^*]dF(x)$$

$$(2.13b) \quad w(0) = b.$$

Because $w^* > b$ is required for participation and the right side of (2.13a) is non-negative for all $w(\tau) < w^*$,

$$(2.14) \qquad w^* > w(\tau) > b \text{ and } dw(\tau)/d\tau > 0$$

for any willing participant with the inequalities holding strictly when the participation condition of (2.9) holds strictly. In other words, the reservation wage falls toward the value of leisure with search tenure as the limit T of the search period is approached.

The explanation of a reservation wage that declines with search tenure given by this version of the model is that the likelihood of finding a better wage in the future diminishes as time passes. The chance that the worker takes of running out of the means of financing further search increases as time passes. In the end, the worker must accept any wage that will compensate for the value of leisure. However, one would not expect a worker facing an imperfect capital market to be risk neutral, i.e., act as if he were simply an expected wealth maximizer operating subject to a liquidity constraint, as we have assumed. Fortunately, Danforth [1979] has established the essence of the conclusion, namely that the reservation wage and financial wealth are positively related, in the more general context of a risk averse worker.

B. The Duration of Search Spells

Obviously, wage search theory views the time spent searching for an acceptable job as a "productive" activity, at least from the point of view of the searching worker. Hence, to the extent that non-employed workers who are classified as unemployed are searching, the theory suggests that "unemployment" is a productive state of labor force participation. This inference caused a lot of controversy in the early '70s, particularly among the then still dominant school of Keynesian macro economics.

However, for labor economists trained in the neo-classical tradition of Marshallian micro economics, this idea was not so objectionable. Even the institutionalist school had a certain sympathy for a theory that dealt with some of the dynamic questions which they had long insisted were important but outside the supply and demand model. A number of labor economists soon found in the theory an optimizing framework that would permit the formation of empirically meaningful hypotheses about phenomena that quite simply could not be explained by either Marshall's or Keynes' theoretical structures. The obvious set of hypotheses that the original model wage search generates concern the distribution of search-unemployment spell lengths.

Given a stationary reservation wage, w^*, the probabilistic rate at which a worker escapes unemployment is simply

$$\phi = \lambda[1-F(w^*)] \tag{2.15}$$

the rate at which offers arrive times the probability that a random offer is acceptable. Since the escape or "hazard" rate is the instantaneous probability of leaving unemployment given unemployment at any date, the constant reservation wage model predicts that the length of a completed search-unemployment spell is distributed exponential with mean equal to the inverse of the escape rate. In the more general case of a reservation wage that varies with the duration of search to date, $w(t)$, because say the worker is liquidity constrained in the manner modeled in the previous section, the distribution of completed spells is given by

$$P(t) = 1 - \exp(-\int_0^t \phi(\tau)d\tau) \text{ where } \phi(t) = \lambda[1-F(w(t))]. \tag{2.16}$$

In this case $\phi'(t) > 0$, the hazard rate is said to exhibit positive duration dependence. Hence, the wage search model not only makes suggestions about what to include in a duration of search regression but has implications for the distribution of the observed random variable.

In the remainder of this section, we focus on the implications of the model for the determinants of the reservation wage and the rate of escape from unemployment in the constant reservation wage case. In the analysis to follow, it is important to note that there is both a direct and an indirect effect of changes in the "demand" factors in the model — the offer arrival rate and the wage offer distribution — on the escape rate. The direct effect is that obtained holding the reservation wage constant and the indirect effect is the change in the escape rate induced by a change in the reservation wage. Of course, other parameters affect only the reservation wage and these — the value of leisure, the cost of search and the interest rate — might be regarded as the "supply" factors is the model. For these there is no direct effect on the escape rate, only an indirect effect. Specifically, the fundamental equation of the decision model, equation (2.8), implies that the reservation wage increases with the value of leisure and decreases with both the cost of search and the interest rate. (Simply completely differentiate the equation.) Hence, these facts and (2.15) imply that the rate of escape from unemployment decreases with the value of leisure but increases with the cost of search and the rate at which future returns to search are discounted. All of these implications are easily understood given the fact that the time spent searching is an investment made now in return for higher income in the future.

The distribution of wage offers, $F(w)$, summarizes a workers employment opportunities given job availability and job availability is indicated by the offer arrival rate λ. These two elements represent two different aspects of the "demand" for the worker's services. We begin our analyses of these by considering the effects of changes in the "mean" and "variance" of the wage offer distribution holding constant the offer arrival rate. Because we do not wish to specify a specific functional form for this distribution, the results below make use of well known generalized notions of mean and variance.

A cumulative distribution function G is said to be a "translation" of another, F, if there exists a constant μ such that

$$(2.17) \qquad G(w+\mu) = F(w) \quad \text{for all } w.$$

For $\mu > 0$, the translation is to the right and G is said to first order stochastically dominate F in the statistics literature. Of course, G can be formed from F by shifting the latter uniformly to the right a distance μ. Clearly, then, the mean of G is exactly μ units larger than the mean of F but all higher moments around the mean are the same for both distributions. Hence,

$$\lim_{\mu\to 0}\{[G(w)-F(w)]/\mu\} = \lim_{\mu\to 0}[G(w)-G(w+\mu)]/\mu = -F'(w),$$

which tells us that a marginal increase in the mean of F, holding other moments constant, decreases the probability of obtaining an offer less than or equal to the given value w by an amount equal to the density of F at w, at least when F is differentiable which we assume for the purposes of this analysis.

The now standard generalized notion of the "variance" is that introduced into the economics literature under the name "mean preserving spread" by Rothschild and Stiglitz [1970]. The distribution H is a mean preserving spread of F given that both are defined on the positive reals and have the same mean if and only if

$$\int_0^w H(x)dx \geq \int_0^w F(x)dx \text{ for all } w > 0.$$

Hence, if one regards $H(w,\sigma)$ as a family of mean preserving spreads of F where σ is a parameter of relative dispersion so that $\sigma = 0$ defines the member F, then

$$(2.18) \qquad \lim_{\sigma \to 0} \int_0^w \{[H(x,\sigma)-F(x)]/\sigma\} dx = \int_0^w H_\sigma(x,0)dx \geq 0 \text{ for all } w$$

where $H_\sigma(x,\sigma)$ is the partial derivative of $H(\cdot)$ with respect to σ.

These two concepts are useful for our purpose because of the following transformation:

$$(2.19) \qquad \int_w^\infty [x-w]dF(x) = E_F\{x\} - w + \int_0^w F(x)dx, \quad \infty > w \geq 0.$$

This fact can be verified by noting that the two sides are indeed equal when $w = 0$ and that the two expressions have the same derivative. As a consequence, equation (2.8) can be rewritten as

$$(2.20) \qquad (\lambda+r)w^* = \lambda E_F\{x\} + \lambda \int_0^{w^*} F(x)dx + r(b-c).$$

Defining $w^*(\mu)$ as the reservation wage associated with the translation G of F defined in equation (2.17), we have

$$(\lambda+r)w^*(\mu) = \lambda E_G\{x\} + \lambda\int_0^{w^*(\mu)} G(x)dx + r(b-c)$$

$$= \lambda\mu + \lambda E_F\{x\} + \lambda\int_0^{w^*(\mu)} F(x-\mu)dx + r(b-c).$$

Therefore,

$$(2.21) \qquad \frac{\partial w^*}{\partial\mu} = \frac{\lambda[1-F(w^*)]}{r+\lambda[1-F(w^*)]} = \frac{\phi}{r+\phi} > 0 \text{ and less than } 1.$$

In words, an increase in the mean of the wage offer distribution increases the reservation wage but by an amount which is less than the increase in the mean. Note that the response is very close to unity when the rate of escape from unemployment is large relative to the interest rate. Indeed, the response is exactly the discount factor one would apply to a dollar expected to be received $1/\phi$ periods hence, which is the expected time until employment at every date during the search process.

In the case of an increase in mean preserving spread, let $w^*(\sigma)$ denote the reservation wage associated with the more spread distribution $H(w,\sigma)$. Since this distribution and F have the same mean by definition.

$$(1+r)w^*(\sigma) = E_F\{x\} + \lambda\int_0^{w^*(\sigma)} H(x,\sigma)dx + r(b-c).$$

Consequently, a marginal increase in spread also increases the reservation wage by virtue of (2.18), i.e.,

$$(2.22) \qquad \frac{\partial w^*}{\partial\sigma} = [\lambda\int_0^{w^*(\sigma)} H_\sigma(x,0)dx]/(r+\phi) \geqslant 0.$$

This famous result from the stopping literature has its own economic translation. Shoppers love bargains and bargains are only possible when prices are disperse. More seriously, it is the consequence of the fact that the worker has the option of waiting for an offer in the upper tail of the wage distribution.

We have already warned the reader that a knowledge of the comparative static results regarding the relationship between the wage is not sufficient for valid inferences about the relationship between the probability of escape from search unemployment and those same parameters. In the case of the mean,

$$\phi(\mu) = \lambda[1-G(w^*(\mu))] = \lambda[1-F(w^*(\mu)-\mu)]$$

by virtue of (2.15) and (2.17). Consequently, a marginal increase in the mean increases the escape probability because the reservation wage increases by less, i.e.,

$$\frac{\partial\phi}{\partial\mu} = F'/(w^*)[1-\phi/(\phi+r)] > 0, \tag{2.23}$$

but the effect will be very small if the escape rate is large relative to the interest rate. In the case of spread,

$$\phi(\sigma) = \lambda[1-H(w^*(\sigma),\sigma)].$$

Therefore, the marginal effect

(2.24) $$\frac{\partial\phi}{\partial\sigma} = -\lambda F'(w^*)\,\frac{\partial w^*}{\partial\sigma} - \lambda H_\sigma(w^*,0)$$

has an ambiguous sign in general.

An increase in job availability as measured by the instantaneous rate at which a worker receives offers, λ, increases the reservation wage by virtue of (2.20), as one would expect. However, given the reservation wage, the same increase also increases the escape rate by virtue of (2.15). The net effect is the sum of the positive direct effect and negative indirect effect. Formally,

(2.25) $$\frac{\partial\phi}{\partial\lambda} = [1-F(w^*)] - \lambda F'(w^*)\frac{\partial w^*}{\partial\lambda}$$

where

(2.26) $$\frac{\partial w^*}{\partial\lambda} = \int_{w^*}^{\infty} [x-w^*]dF(x)/[r+\phi] > 0.$$

Burdett [1981] shows that the net effect can be negative although a sufficient condition for the intuitively plausible implication that an increase in job availability reduces the expected duration of a search unemployment spell is a "log-concave" wage offer probability density function.

C. Problems in and Methods of Estimation

One of the first empirical applications of the wage search model concerns the analysis of the effects of unemployment insurance benefits on the duration of unemployment. Numerous authors realized that the value of leisure b can be interpreted to include the insurance benefit paid to covered employed workers. Hence, the model's prediction that the reservation wage increases with the value of leisure also implies that those who receive benefits relative to like workers who don't and those receiving relatively higher benefits under the program should be observed to experience longer unemployment spells. Furthermore, their post unemployment spell wage should be higher. An extensive empirical literature was born that continues to live today devoted to testing and estimating these and related effects of UI.[7]

The standard econometric methodology applied in the early work is the O.L.S. estimation of "reduced form" relationships between both observed unemployment spell lengths and post unemployment earnings and various measures of the liberality of UI benefits, typically replacement ratios and maximum benefit period lengths. Generally speaking, the evidence obtained from many data sources supports the hypothesis that unemployment durations are affected as expected although the evidence on the effects on post unemployment wage is less clear. There are numerous criticisms that can and have been made of the methodological approach taken. (See Welch [1977]). Since actual observations on worker reservation wages are not typically available, the method does not permit a test of the mechanism of causality suggested by the wage search model. Duration observations drawn from any finite period of observation will include many incomplete spells. Observations on the eventual wage are not available for workers who do not complete their spells within the observation period. OLS estimates are biased when these spells are excluded, which was typically done. Finally, the expected length of the spell and the expected post spell wage are jointly determined endogenous variables for each individual.

Unlike most theories of individual economic decisions that are set in the context of a deterministic environment, search theory explicitly deals with the uncertain world that the worker faces when attempting to find a job. As a consequence, the theory has implications for the stochastic relationship one might expect between "endogenous" and "exogenous" variables as well as the qualitative relationships between them. Specifically, if the reservation wage is stationary, then the distribution of the length of a worker's completed search unemployment spell is exponential with a hazard rate proportional to the probability of sampling an acceptable wage offer and the distribution of the worker's post spell wage is the conditional distribution of wage offers given that it exceeds the reservation wage. Recent empirical work by Kiefer and Neumann [1979a, 1979b, 1981], Nickell [1979], Lancaster and Nickell [1980], and Flinn and Heckman [1982b] exploit these properties. Although it is not my role in this essay to deal with either the econometrics of estimation or to report on actual estimates obtained, it is useful to illustrate the relationship that does exist between stochastic sequential search models and empirical specification.

Suppose that one has access to observations that include for each of n individuals a post unemployment spell wage and the completed length of the spell, denoted as

$$(2.27) \qquad (w_i, t_i), \quad i=1,2,\ldots,n.$$

Imagine that the value of leisure net of search cost and the mean wage offer are also observed which are denoted as

$$(2.28) \qquad (b_i - c_i, \mu_i), \quad i-1,2,\ldots,n.$$

Assume that the wage offer distribution is from a two parameter family with common known form for all workers, an individual mean, and a common but unknown variance σ^2. Further suppose that the offer arrival rate λ, to be estimated, is the same for all workers. Then, conditional on the worker's reservation wage, the model implies the following distributions of the two endogenous variables as we have already noted.

$$\Pr\{w_i < w\} = F(w;\mu_i,\sigma^2)/[1-F(w_i^*;\mu_i,\sigma^2)] \tag{2.29}$$

$$\Pr\{t_i < t\} = 1-\exp(-\lambda[1-F(w_i^*;\mu_i, \sigma^2)]t). \tag{2.30}$$

It follows immediately that the contribution of the individual to the sample likelihood is

$$L_i = \frac{F'(w_i;\mu_i,\sigma^2)}{[1-F(w_i^*;\mu_i,\sigma^2)]}\sigma\times[1-F(w_i^*;\mu_i,\sigma^2)]\exp(-\lambda[1-F(w_i^*;\mu_i,\sigma^2)]t_i),$$

the product to the probability densities associated with the wage and spell length observations. Hence, the sample log likelihood function given the data and the individual reservation wages is

$$\ell nL = \sum_1^n \{\ell nF'(w_i;\mu_i,\sigma^2) + \ell n\lambda - \lambda[1-F(w_i^*;\mu_i,\sigma^2)]t_i\}. \tag{2.31}$$

Were one able to observe each worker's reservation wage, maximum likelihood estimates of the unknown parameters, the common offer arrival rate and variance, could be obtained in the obvious manner. Although the reservation wage is not observed by assumption, it is a function of the data implicitly specified by equation (2.8). A reasonable approximation is the linear form

$$w_i^* = \alpha + \beta(b_i - c_i) + \gamma\mu_i. \tag{2.32}$$

Furthermore, for a common positive interest rate, the decision model implies the restrictions

$$\beta > 0,\ \gamma > 0,\ \text{and}\ \beta + \gamma = 1. \tag{2.33}$$

Hence, by substituting for the individual's reservation wage rates in (2.31) from (2.32), one observes that the parameters of the reservation wage equation can be estimated and the restrictions tested as well, at least in principle. In practice, some spells observed in a finite time interval will not be complete. Such spells are said to be censored. Statistical methods for appropriately estimating duration distributions with a mix of complete and censored duration observations is the subject matter of "survival" or "failure time" analysis. Kalbfleish and Prentice [1980] provide an extensive recent treatment of the subject.

Although natural extensions of the method can be used to test for the positive duration dependence in the hazard rate implied by a falling reservation wage in principle, unobserved heterogeneity complicates the issue. Contrary to the hypothetical example outlined above, the econometrician does not observe either the mean wage offer, μ, or the opportunity cost of accepting employment, b-c, for each worker in the sample. Instead, worker characteristics are observed which only proxy for these determinants of the reservation wage. One might expect that the observed characteristics do not capture all relevant differences in the determinants of reservation wage differences across the individuals in a given sample. It is now well known that unobserved heterogeneity of this form induces spurious negative duration dependence. Specifically, for any observationally equivalent subsample, the fact that those with higher individual hazards will leave unemployment sooner implies that fraction of those still unemployed who leave unemployment per period will fall with the observed duration of unemployment even if the hazard for each individual exhibits no duration dependence. (See Salant [1977] and Heckman and Borjas Borjas [1980] for discussions of this point.)

In their test of the constant reservation wage hypothesis Keifer and Neumann [1981] apply the so-called "random effect" model to correct for unobserved heterogeneity. For a discussion of the econometrics of the problem, see Flinn and Heckman [1982b]. Heckman and Singer [1982] study the problem of identifying duration dependence when unobserved heterogeneity is present and develop a non-parametric approach for estimating duration dependence in search and related models.

III. Job Turnover, Earnings Paths, and Participation Histories

The purpose of this section is to describe several important extensions of the original wage search model that have been developed to help understand job turnover, the dynamic behavior of earnings, and the labor market experiences of individual workers more generally over time. As the title of the section suggests, the substantive topic coverage of the literature discussed in the section is quite varied. What ties this literature together is the common approach taken by many different authors to a variety of worker labor supply decisions that arise in a dynamic context. The principal starting point for all the research reviewed is that the worker lives in a changing environment that requires a continual reevaluation of the decision of whether to work now and/or to seek some employment opportunity in the future under conditions of uncertainty. Each of the models reviewed considers a particular version of this problem using a theoretical framework which is derivative of the original model of unemployed search.

It is important to point out that the literature on subsequent developments not included for discussion in this section is far vaster than that which is presented. For example, a review of recent contributions to the literature on the effects of the unemployment compensation system on individual search decisions and on unemployment behavior could now fill a volume. Furthermore, not all contributors to the innovations that are discussed in this section get equal treatment. Instead, my method of presentation has biased my choices in favor of those authors with models that can be conveniently presented within the decision theoretic framework developed in the first section.

A. Search On the Job

The assumption that workers search only while unemployed is obviously not realistic and subject to criticism. Tobin [1972] makes the point that one observes hardly any search unemployment among many professions, his own for example. The available quantitative information about the process by which workers make transitions to employment and from one job to another is very limited. However, in his review of the available evidence, Mattila [1974] concludes that indeed most workers who quit move to another job without an intervening period of non-employment. More recently, Topel [1973] reports that the vast majority of workers classified as unemployed in the C.P.S. were laid off. These facts suggest the need for allowing search to take place while employed as a means of understanding the behavior of unemployed workers and understanding of the job turnover process.

The model of worker search while employed presented here is constructed in the image of the original developed by Burdett [1978]. Although there are reasons to believe that the cost of search is higher for many when employed than it is when unemployed, only the results for the case of no differential will be presented here.[8] An important implication of the model in this case is that the reservation wage of an unemployed worker is simply the value of "leisure" as in the classical participation model. Specifically, when the cost of search is the same when employed or not, the worker accepts the first job that compensates for the value of foregone leisure and then generally continues to search for a higher paying one while employed.

Although this result establishes that speculative waiting to find a higher paying job need not contribute to unemployment, it does not imply that the worker search behavior while unemployed is unimportant as a determinant of the unemployment rate. Specifically, if the intensity with which the worker searches as well as when to accept employment is a part of the search decision, then as before the distribution search unemployment durations is endogenous as Burdett and Mortensen [1980] have shown. The search on the job model presented here includes a search intensity decision for the purpose of analyzing this dependence.

The assumption that workers can only search or not obviously abstracts from the reality that a worker can and does decide to devote more or less effort to search activities. From the worker's point of view, the purpose of searching more intensely is to shorten the expected time period required to find an acceptable or better job. However, one expects that the returns to more intensive search diminish, at least beyond some point. The simplest way to build these features into the model is to assume that the offer arrival rate is proportional to the worker's "search effort" and that the cost of search is an increasing convex function of "effort". In other words, let $s\lambda$ denote the offer arrival rate and $c(s)$ the cost of search function where s represents search effort. In this generalization, λ is a market determined search efficiency parameter or "potential" offer arrival rate. An increasing marginal cost of search requires that the cost function has the properties $c(0) = 0$, $c'(s) > 0$ and $c''(s) > 0$. Notice that the original model can be regarded as the boundary case of a constant marginal cost on the unit interval and an infinite cost beyond.[9]

Let b represent the value of leisure, r the discount rate and $F(w)$ the distribution of wage offers as before. A worker's search strategy is now a choice of the lowest acceptable employment wage and an intensity of search effort both when not employed and employed at a particular wage. Let V denote the worker's discounted future net income, with appropriate account taken of the value of leisure, when unemployed given that an optimal search strategy is pursued in the future and let $W(w)$ represent the value of being employed at wage w given the optimal search strategy.

Since the current search effort affects only the cost of search incurred now and the probability of generating an offer in the next instant, its optimal value maximizes the sum of today's income net of search costs and the expected capital gain attributable to search. Hence, when the worker is unemployed

$$(3.1) \qquad rV = \max_{s \geq 0}[b-c(s) + \lambda s\int_0^\infty \{\max[V,W(x)]-V\}\,dF(x)]$$

while when employed at a wage w

$$(3.2) \qquad rW(w) = \max_{s \geq 0}[w-c(s) + \lambda s\int_0^\infty \{\max[V,W(x),W(w)]-W(w)\}\,dF(x)].$$

These equations are natural extensions of (2.6).

Equation (3.2) implies that the value of employment increases with the wage received.[10] Therefore, a comparison of (3.1) and (3.2) imply that the value of leisure is the lowest wage at which the worker will accept employment, i.e.,

$$(3.3) \qquad V = W(b) < W(w) \text{ for all } w > b.$$

Given this fact, the first order conditions for the search intensity choice problems on the right sides of (3.1) and (3.2) can be written as

$$(3.4) \qquad \lambda\int_w^\infty [W(x)-W(w)]dF(x) = (<)\ c'(s^*(w)) \text{ as } s^*(w) > (=)\ 0.$$

where $s^*(w)$ is the optimal search intensity choice when the worker is employed at wage $w > b$ and $s^*(b)$ is the choice when the worker is unemployed. In other words, optimal search effort equates its marginal return and cost. Because $W(w)$ is strictly increasing, equation (3.4) and the assumption of increasing marginal cost of effort imply that the optimal search effort declines with the wage earned while employed. Finally, at some sufficiently high wage, w^*, and beyond the return won't justify the cost of positive search effort at the margin. Since equation (3.2) implies that $W(w) = w/r$ when $s = 0$, the critical wage, properly called the search reservation wage, solves

$$(3.5) \qquad (\lambda/r)\int_{w^*}^{\infty} [x-w^*]dF(x) = c'(0).$$

Finally, the unemployed worker is willing to search if and only if the marginal return to search effort at wage b exceeds the marginal cost of no search effort, i.e., $w^* > b$.

In sum, we have established that

$$(3.6a) \qquad s^*(b) > 0 \text{ if and only if } w^* > b,$$

$$(3.6b) \qquad ds^*(w)/dw < 0 \text{ for all } b \leq w < w^*, \text{ and}$$

$$(3.6c) \qquad s^*(w) = 0 \text{ for all } w \geq w^*.$$

These results have the following interpretations. The worker is a participant in the sense that he or she looks for employment when unemployed when the marginal return to search effort evaluated at the value of leisure exceeds the marginal cost of effort evaluated at no effort. If a participant, the worker accepts the first job that compensates for the value of leisure and then generally continues to search with an intensity that equates the marginal cost and return to effort. Because the return to search effort declines with the wage earned, so does the optimal search effort choice. Finally, once a sufficiently well paid job is found, the worker stops searching altogether.

The search on the job extension of the basic model contains a theory for both the completed lengths of unemployed search and job spells. Specifically, both are exponential distributions with constant "hazard" rate

$$(3.7) \qquad \phi(w) = \lambda s^{*}(w)[1-F(w)], \; w > b,$$

where the hazard is the instantaneous rate of escape from unemployment when $w = b$ and is the worker's instantaneous quit rate when the worker is employed at wage $b < w$. Hence, in this model, the expected duration of search unemployment declines with the value of leisure both because optimal search effort and the probability of finding an acceptable wage decline with the value of leisure. The quit rate when employed declines with the wage earned for analogous reasons. The latter implication of the model is consistent with virtually every empirical study of quit behavior, e.g., see Pencavel [1970], Parsons [1977], and Mincer and Jovanovic [1981].

As Burdett [1978] points out, the model also provides an alternative explanation for why wages generally increase with years of work experience. The standard argument is that workers become more productive with experience as a consequence of learning and training. Here earnings rise because workers with longer experience are more likely to have found a higher paying job. Formally, the model implies that the wage process for an individual over time $\{w(t)\}$ is Markov with state space X, the support of the wage offer distribution F. The instantaneous rate of transition from the current wage w to any other $x \neq w$ in the support of F is zero if $x < w$ and is the product of the rate at which new offers arrive, $\lambda s^*(w)$, and the probability density of receiving the offer x, $F'(x)$, when $x > w$. By virtue of (3.6c), the set $\{x > w^*\}$ are the absorbing states of the process and the stationary distribution of the process, which represents the distribution of earnings that any worker can expect in the "long run", is given by $F(x)/[1-F(w^*)]$ defined on set of absorbing states. Hence, the implied time path of an individual's wage is a stochastically increasing function of length of work experience which is eventually absorbed into the set where the worker is no longer motivated to search.

It is important both conceptually and from an econometric point of view that one not confuse the hypothesis that the quit rate for a given individual declines with the wage earned across jobs with the cross individual effect of different earnings opportunities on their respective quit rates. In this model, the latter is the effect of a change in the mean wage offer on the individual's quit rate holding current earnings constant. This effect can be derived by first using the fact that equations (3.2) and (3.4) imply

$$(3.8) \qquad rW(w)-w = s^*(w)c'(s^*(w))-c(s^*(w)).$$

By the convexity of the cost of search effort function, the right side of (8) is positive and increasing in $s^*(w)$. Therefore, the optimal search effort given the wage currently paid and the interest rate, increases with $W(w)$, the worker's future discounted net income stream given that his or her current wage is w. Not surprising, the latter can be shown to increase with a right translation of F, i.e., a ceteris paribus increase in the mean of the wage offer distribution. Since $F(w)$ decreases at every value of w given such a change, the theory predicts that workers facing wage offer distributions with higher means, holding other moments constant and holding the wage currently earned constant, quit more frequently and have more steeply sloped wage experience profiles. Finally, the same argument implies that the rate of escape from unemployment is higher for workers facing a wage offer distribution that is more favorable in this sense. Since the effects of a ceteris paribus increase in the wage currently earned and in the mean wage offer expected are opposite in sign and workers who do face a more favorable wage offer distribution are more likely to be paid more in any sample, the estimated wage "coefficient" in any quit equation is upward biased unless care is taken to include human capital and ability variables that adequantely condition for this form of worker heterogeneity.

In the preceding discussion it was asserted that a worker's wealth given the wage currently earned increases with the mean of the wage offer distribution, which we denote as μ. One might also expect that wealth increases with the offer arrival rate parameter λ. However, a formal demonstration of these conjectures requires a more powerful method than that applied in the case of the original stopping version of the model. Because we will have need of the method in the subsequent exposition and because it can also be used here to obtain results concerning the qualitative relationship between maximal wealth and other parameters characterizing the worker's environment, the remainder of this subsection is devoted to a brief outline of the method.

Let $F(w,\mu)$ denote a family of offer distribution that differ only with respect to their means parameterized by μ. Specifically, one member of the family is a right translation of the other if and only if its μ is greater than the other's. Let $W(w,\mu,\lambda)$ denote the maximal discounted expected future worker net income stream when employed at a wage w given that the worker's mean wage offer in the future is μ and offer arrival rate parameter is λ. Let $s^*(w,\mu,\lambda)$ represent the optimal search effort given w, a wage offer distribution with mean μ and offer arrival parameter λ. Now, observe that equation (3.2), given condition (3.3), can be rewritten as

$$(3.9)\qquad W(w,\mu,\lambda) = \max_{s\geq 0}\{[w-c(s) + \lambda s\int_w^\infty W(x,\mu,\lambda)dF(x,\mu)]/[r+\lambda s[1-F(w,\mu)]]\}$$

$$= \max_{s\geq 0}\{\frac{w-c(s)}{r} + \beta(s,w,\mu,\lambda)[\int_w^\infty W(x,\mu,\lambda)\,\frac{dF(x,\mu)}{1-F(w,\mu)} - \frac{w-c(s)}{r}]\}$$

where

$$(3.10)\qquad \beta(s,w,\mu,\lambda) = \lambda s[1-F(w,\mu)]/[r+\lambda s[1-F(w,\mu)].$$

The right side of (3.9) is a map that transforms an arbitrary bounded, continuous function defined on $[0,\infty)\times[0,\infty)\times[0,\infty0)$ into another with the same range and $W(w,\mu,\lambda)$ is a fixed point of the map. Furthermore, $r>0$, $s^*(b,\mu,\lambda)$ bounded, which is quaranteed by the assumption that $c'(s)$ tends to infinity with s for all finite μ, $F(0) = 0$ and (3.6b) imply

$$(3.11)\qquad 0 \leq \beta(s^*(w,\mu,\lambda),\ w,\mu) \leq \beta(s^*(b,\mu,\lambda),b,\mu,\lambda) \equiv \beta < 1 \text{ for all } w \geq b.$$

Blackwell [1965] has shown that any such transformation $T(W)$ is a contraction map if (i) $|\ T(W+\delta)\ |\geq|\ T(W)\ |$ for every positive constant δ and (ii) a non-negative constant $\beta < 1$ exists such that $|T(W+\delta)\ |\leq|\ T(W)| + \beta\delta$

where $|\cdot|$ denotes the sup norm. A contraction map has the property that any sequence of functions generated by repeated application of the transformation converges to its unique fixed point. Since (3.9-(3.11) imply that the conditions are satisfied, the value function $W(w,\mu,\lambda)$ is uniquely defined. This argument is a standard method for demonstrating the existence and uniqueness of a solution to stochastic dynamic infinite horizon programming problem.

However, notice that if the value function $W(w,\mu,\lambda)$ is differentiable with respect to the mean wage offer, then the partial differential function, $W_\mu(\cdot)$, must satisfy the following equation by virtue of a complete differentiation of equation (3.9) with respect to μ:

$$(3.12) \qquad W_\mu(w,\mu,\lambda) = \beta_\mu(s^*(w,\mu,\lambda),w,\mu)[\int_w^\infty W(x,\mu,\lambda)\,\frac{dF(x,\mu)}{[1-F(w,\mu)]} - \frac{w-c(s)}{r}]$$

$$+ \beta(s^*(w,\mu),w,\mu,\lambda)\ [\int_w^\infty W(x,\mu,\lambda)\,\frac{\partial}{\partial\mu}\,(\frac{F'(x,\mu)}{1-F(w,\mu)]})]\,dx$$

$$+ \beta(s^*(w,\mu),w,\mu,\lambda)\int_w^\infty W_\mu(x,\mu,\lambda)dF(x,\mu)/[1/F(w,\mu)].$$

Hence, Blackwell's conditions also imply that the right side of (3.12) is a contraction map which has as its fixed point the partial derivative function of interest. Therefore, the fact that any sequence of functions obtained by repeated application of the transformation converges to the fixed point, the fact that both the first and the second terms on the right of (3.12) are non-negative if $s^*(\cdot) > 0$, and finally an appropriately constructed induction argument imply the desired result. Because $\beta(\cdot)$ is also strictly increasing in the offer arrival parameter when $s^*(\cdot) > 0$, an analogous argument implies that the worker's wealth increases with λ as well. In sum,

$$(3.13) \qquad W_{\mu}(w,\mu,\lambda) > 0 \text{ and } W_{\lambda}(w,\mu,\lambda) > 0 \text{ if and only if } w < w^{*}.$$

Of course, $W_{\mu}(w,\mu,\lambda) = w/r$ for all $w > w^{*}$ by virtue of equations (3.6) and (3.8) implies necessity.

That the first term on the right side of (3.12) is positive is implied by the definition of $\beta(\cdot)$ given in (3.10), the fact that $F(w,\mu)$ is decreasing in μ for every w, and the fact that the term in square brackets is positive which is implied by equation (3.8). The second term is positive because $W(x,\mu,\lambda)$ is increasing in x given μ and because the distribution of acceptable offers is stochastically increasing in μ. Construct the sequence

$$W_{\mu}^{n}(\cdot) = T(W_{\mu}^{n-1}(\cdot)) \quad , \; W_{\mu}^{0}(w,\mu) \equiv 0$$

where $T(\cdot)$ is the transformation defined by the right side of (3.12). Every element is positive for all $n > 0$ by induction given $w < w^{*}$. The fact that $T(\cdot)$ is a contraction implies that the sequence converges to the function of interest. Hence, the fact that every element in the tail is positive and convergence imply (3.13).

Finally, the conditions of (3.13) and equation (3.8) imply

$$(3.14) \qquad \partial s^{*}(\cdot)/\partial\mu > 0 \text{ and } \partial s^{*}(\cdot)/\partial\lambda \geq 0 \text{ if and only if } w < w^{*}.$$

Therefore, the hazard in equation (3.7) in increasing in both the mean wage offer, μ, and the offer arrival parameter, λ, for all wage rates less than or equal to the search reservation wage w^{*}. Note that the latter implication requires no restriction on the form of the offer distribution function as it does in the standard stopping model which assumes only search while unemployed.

B. Learning About the Job

In the original search model and the search on the job extension, the job offering a particular package of characteristics must be found but the nature of those characteristics for a located job is known. The consequences of relaxing this assumption have been studied by Jovanovic [1979a, 1979b], Wilde [1979], Viscusi [1979] and Johnson [1978]. The principal idea common to this literature is that the worker does not know for sure the future earning stream or some other relevant characteristics of a job at the date of hire. Instead, he or she must spend some time trying it on for size. As more information about the job characteristics is acquired, the decision to stick with it is continually reconsidered. A quit in this framework results as a consequence of a decision that the job is "not a good fit" relative to alternatives available. In short, some important dimensions of jobs are in Hirshleifer's [1973] terminology "experience goods" rather than "inspection goods", as the standard search model supposes. The results drawn from this literature have materially added to the list of hypotheses concerning and explanations for job separation behavior. Furthermore, the analysis represents the first formalization of the "job shopping" explanation for high turnover among the young.

Although the authors' stories vary, Jovanovic assumes that the learning is about productivity on the job while Wilde and Viscusi focus on learning about non-pecuniary job characteristics, the basic formulation of the decision problem is the same. The worker acts as a Bayesian forecaster by using observations to date to make predictions concerning the job's true but unknown characteristics. As new information arrives, the forecast is revised and a quit decision is made. The probability of quitting, then, depends on the information acquired about the job at the time of decision. Formally, the problem is again one of stopping, but now similar to Rothschild's [1974] version of the price search model where the worker must learn about the distribution of offers. As such, its essential features can be illustrated using the machinery we have already developed.

In this section, I have chosen to present Jovanovic's model because of its close relationship to the original wage search model and its focus on wage and turnover dynamics. In Jovanovic's model a worker's future productivity is purely "match specific". Ex ante there is no information that allows a differential prediction concerning the productivity of a given job-worker match. Specifically, a worker's productivities across matches are independent in the sense that performance in one provides no information about productivity on another. In other words, one can view any sequence of realized average future firm-specific productivities as random and independent draws from the same distribution. Were these realizations observable at the time of hire and if the wage rate at each firm were some strictly increasing functions of these realizations, then the original wage search model applies, i.e., the wage-productivity relation and distribtuion of productivities generate the wage offer distribution. The worker's acceptance decision is the choice of whether or not to continue sampling match specific productivities from this distribution.[11]

Assume that productivity in any job is not immediately observed. Instead, the worker's realized output is observed by both worker and employer and provides a noisy signal for average output over the future tenure of the match. This information is used both to set the current wage and to forecast future earnings for the purpose of making the separation decision. Of course, the conditional predictor of future productivity, given average output to date, becomes increasingly more precise as a consequence of the law of large number. In the limit the worker's average productivity is known with certainty, provided, of course, that he or she hasn't already decided to leave. As this description suggests, the quit problem is of the "two armed bandit" variety and shares its properties.[12] Once separated, the worker will not return. Therefore, the probability that the worker will leave even when the true average match specific productivity is higher than any other is positive as a consequence of sampling variation.

Jovanovic maintains the risk neutral and infinite life abstractions that characterize much of the job search literature and assumes that the worker is paid a wage equal to conditional expected value of his true productivity given all available information to date. Under these assumptions and the assumption that the common distribution from which match specific true productivities are drawn is known, the value of leaving the current job is some constant, V, which represents the discounted future income that the worker can expect were he to try any other job. As indicated by the notation, it is the analogue to the value of search in the original model. The worker quits whenever the value of continuing to work at the job, which will be denoted as a random variable, $W(\cdot)$, to be determined, falls below V. Stopping, then, corresponds to quitting the current job to try another and the probability of stopping is the quit probability. Below we outline the specifics which differ from Jovanovics in order to take advantage of the theoretical apparatus on hand. However, these differences do not violate the spirit of his model; rather they make his results more transparent.

Let $t > 0$ denote the worker's tenure on some specific job, and let $\{x(t)\}$ represent the stochastic process generating the time path of realized productivities on the job so long as the worker continues. Imagine that changes in observed productivity occur as random dates over the worker's tenure on the job and that the arrival of new values is a Poisson process characterized by a constant arrival rate η. [13] Further suppose that the new values of productivity are drawn independently from the same and, for simplicity, normal distribution with unknown mean μ, drawn at the time of hire, and known variance σ^2. Following Jovanovic, the worker's true expected productivity over the life of the match is distributed normal with known mean m and variance s.

The stochastic specification is consistent with Jovanovic's except that a continuous jump process with Poisson arrivals of observations on productivity is assumed rather than a Weiner process. The principal advantage of this alternative is that the analysis can be performed using the standard theory of finite sample statistics. Let a sample of n productivity observations be denoted as

$$(3.14) \qquad x_i = \mu + \varepsilon_i, \ i = 1,2, \ldots., n.$$

At any date such a sample provides the information that the worker has about the unknown mean productivity, μ. Given the assumptions that μ is drawn from a normal with mean m and variance s and that the sequence $\{\varepsilon_i\}$ is i.i.d. normal with zero mean and variance σ^2, the posterior distribution of μ given the sample is distributed normal (see De Groot [1970]) with mean

$$(3.15.a) \qquad w(n) = E\{\mu | x_1,\ldots,x_n\} = [m/s + (\sum_{i=1}^{n} x_i)/\sigma^2]s(n)$$

and variance

$$(3.15b) \qquad s(n) = 1/(1/s + n/\sigma^2).$$

As n becomes large, w(n) converges to the sample mean which is converging in probability to the realized known value of μ, the worker's true average productivity with probability one.

Following Jovanovic, the statistic w(n) is assumed to be the wage received by the worker given past productivity observations. Given (3.15), it is convenient and permitted to regard the wage and sample size pair as the sample sufficient statistic for the worker's estimation problem. Let G(w(n+1); w,n) represent the conditional distribution of the wage at the next observation of productivity, given that w(n) = w. By virtue of equations (3.14) and (3.15),

$$(3.16) \qquad w(n+1) = [s(n+1)/s(n)]w(n) + [1-s(n+1)/s(n)][\mu + \varepsilon_{n+1}]$$

Therefore, w(n+1) given w(n) = w is distributed normal with mean

$$E\{w(n+1) | w(n) = w\} = w$$

and variance

$$E\{(w(n+1) - w)^2 | w(n) = w\} = [1-s(n+1)/s(n)]^2[s(n) + \sigma^2]$$

$$= [s(n+1)/\sigma^2]^2[\sigma^2 s(n)/s(n+1)] = s(n+1)s(n)/\sigma^2$$

by virtue of (3.15b). The properties of subsequent interest are that the variance of w(n+1) is independent of the mean w, is decreasing in the size of the sample of realized values of productivity, and converges to zero as that number, n, tends to infinity. The rational worker, assumed to know all that we do, will use the conditional distribution of the next wage given the current wage to make the predictions of future earnings on the job needed to decide whether or not to quit.

The decision to continue on the job or to try another is made by the worker whenever new information about productivity on the job is obtained, at the time of each arrival of a new realized value of productivity. The decision requires a comparison of the worker's expected present value of future income on any randomly selected alternative job, which we denote as V, and the expected present value of future income given that the worker continues on the current job conditional on the information available about his or her productivity on the current job, the sufficient statistic (w,n). Because there is a possibility that the worker will decide to quit the current job at some future date, the value of continuing is a function the wage currently earned, the number of realized productivity observations to date, and V. Because a new realization of the productivity process will arrive during the small future time interval dt with probability ηdt by virtue of the Poisson arrival assumption and because that event will induce the worker to choose between the new value of continuing and the value of quitting, the following analogue to equation (2.6) equation defines the current value of continuing:

$$rW(w,n,V) = w + \eta\int\{\max[W(y,n+1,V),V] - W(w,n,V)\}dG(y;w,n). \tag{3.17}$$

To close the model, we simply note that every job is ex ante identical and that the starting wage in all of them is $w(0) = m$ by virtue of (3.15). Hence,

$$V = W(m,0,V). \tag{3.18}$$

In other words, the value of quitting is the expected present value of future earnings on the first day of any new job.

The logic used to obtain (3.17) is the same as that introduced in section II. The imputed interest income on the expected wealth associated with working on a job that pays wage w after n productivity observations given that V is the alternative wealth associated with trying another job is equal to the current wage plus the expected capital gain associated with the process generating future wage rates on the current job and the option to quit in the future. The existence of a unique value function $W(\cdot)$, which is continuous in w, and a unique constant V that satisfy (3.18) can be established using a modification of methods outlined earlier. Furthermore, one can show that the value of continuing is increasing the the current wage, w, and decreasing in the number of productivity realizations to date, n.

That wealth should increase with the current wage earned is intuitively clear. It both represents current earning on the job at hand and is the forecast of earnings on that job in the future. The reason why the value function declines with the sample size is a bit more subtle. Because the worker has the option of quitting to try another job, worker "prefers risk" in a sense quite analogous to that discussed in the case of the wage search model. The existence of the quit option allows the worker to reject low wage realizations on the current job in the future. As a consequence, he prefers dispersion in the future wage because only the higher realizations are relevant. Formally, this preference for risk is reflected in the properties of the value function $W(\cdot)$; it is strictly convex in w. This fact together with the implication from equation (3.16) that the worker's future wage, conditional on the current wage, has a variance that declines with the sample size to date imply that the value of continuing is a strictly decreasing function of the sample size, n.[14]

These properties of the value function permit a qualitative analysis of the boundary of indifference between quitting and continuing, the set of (w,n) pairs that equate the $W(\cdot)$ and V. The boundary can be characterized in terms of a reservation wage, $w^*(n)$, that is a function of the sample size to date. It solves,

$$W(w^*(n),n,V) = V, \quad n = 0,1.... \tag{3.19}$$

Since $W(\cdot)$ is increasing in w given n, the worker quits when and if the wage process $\{w(n)\}$ falls below the boundary in the sense that $w(n) < w^*(n)$. Because $W(\cdot)$ is also strictly decreasing in the sample size, (3.19) implies that the reservation wage increases with n. Finally, the equations (3.17) and (3.18) and the definition (3.19) imply

$$w^*(n) = rV - \eta\int_{w^*(n+1)}^{\infty} [W(y;n+1,V) - V]dG(y;w^*(n),n) < rV$$

and

$$w^*(0) = m.$$

In sum,

$$(3.20) \qquad m = w^*(0) < w^*(n) < w^*(n+1) < rV, \; n = 1,2, \ldots$$

Furthermore, the reservation wage converges to rV in the limit as n tends to infinity because the variance of the next wage tends to zero.

The economic reasons underlying these results are easily exposited. First, the reservation wage increases with the sample size because rising precision of the estimate of future wage rates on this job implies a falling chance of quitting a job on which the worker is in fact relatively productive. Second, it converges to the imputed interest income on the wealth attributable to trying another job as the sample size grows because there is no uncertainty about the worker's productivity on this job in the limit and rV represents expected future income when the worker quits. Note that (3.20) also implies that the endogenously determined value of rV exceeds m, the worker's expected prior productivity on every job. It does so because the quit decision modelled is a process of search for a relatively high paying job and because rV is the average future income stream equivalent that can be expected by engaging in the process.

Because the reservation wage increases with the size of the sample of past observations on an individual's productivity and because the sample size and tenure on a job are positively correlated, it is at least intuitively clear that those who remain on a given job for any tenure period of length t or more are those who have experienced a relatively favorable and generally increasing sequence of realized productivities. This implication of a rising wage-tenure profile for those who remain on a job can be formalized as follows. Let $Q(w;n)$ denote the probability distribution over a worker's wage given that the worker is still on the job and that n different productivity values have been observed in the past. It is the conditional distribution of the statistic $w(n)$ defined in equation (3.15a) given that the sequence of its previous values exceeds the sequence of reservation wage values, i.e.,

$$(3.21) \qquad Q(w;n) \equiv \Pr\{w(n) \le w \mid w(i) > w^*(i),\ i = 1,2,\ldots,n\}.$$

This distribution improves with n in the sense that higher wage rates are more probable the large is n, $Q(w;n+1) < Q(w;n)$, as a consequence of the selection process induced by the separation decision. To understand why, first note that the unconditional distribution of the random variable $w(n)$ is normal with constant mean m and variance $s-s(n)$ by virtue of the equations of (3.15). Indeed, the sequence $\{w(n)\}$ converges in distribution to μ which is normal with mean m and variance s. The latter would be the eventual distribution of earnings across workers in a large sample were all to stay on the job indefinitely. However, the separation decision selects to retain on the job those workers whose wage sequence stay above the rising sequence of reservation wage rates. Consequently, the distribution given employment on the job and a sample of productivity observations of size n is roughly speaking the normalized right tail of the unconditional distribution of $w(n)$. The tail elongates as n increases and the left truncation point increases with n.

Since the sample size given tenure t for each worker is distributed Poisson with mean ηt the wage distribution across workers who have attained tenure t is

$$(3.22) \qquad P(w;t) = \sum_{n=0}^{\infty} Q(w;n)\exp(-\eta t)(\eta t)^{n}/n!.$$

The positive correlation between sample size and tenure yields the implication that this family of distributions is stochastically increasing in tenure, i.e.,

$$(3.23) \qquad \partial P(w;t)/\partial t = \eta \sum_{n=0}^{\infty} [Q(w;n+1) - Q(w;n)] \exp(-\eta t)(\eta t)^{n}/n! < 0.$$

In words, the faction of those still on the job who receive a higher wage increases with tenure. It follows immediately that the average wage of those who remain on a job

$$(3.24) \qquad E\{w(t)\} = \int w dP\{w,t\}$$

increases with tenure. This fact implies that the learning about the job hypothesis offers an alternative to the on-the-job training hypothesis for observed on the job wage growth.

The dependence of quit rates on the wage earned and tenure attained on the job is another topic of interest in the empirical literature. In this model the probability that the worker quits a job during the short interval (t,t+h) given that the worker's wage at tenure date t is w and the sample size of previous productivity observations is n is the product of the probability that a new observations arrives, ηh, and the probability that the new wage is less than the reservation wage with a sample size of n+1. Hence the instantaneous condition quit rate is

$$q(w,n) = \eta G(w^{*}(n+1);w,n). \tag{3.25}$$

Hence the instantaneous quit rate given the wage and tenure, the "hazard rate" for the distribution of completed job spell lengths given the wage, is

$$\phi(w,t) = E\{q(w,n) \mid w(t) = w\} = \sum_{n=0}^{\infty} q(w,n)\exp(-\eta t)(\eta t)^{n}/n! \tag{3.26}$$

by virtue of the Poisson arrival assumption.

The stylized facts drawn from the literature on empirical quit equations are that the quit rate increases with the wage earned on the job given tenure and decreases with tenure given the wage, holding constant age, work experience, education and other characteristics that are likely to be related to systematic differences in "general" human capital across individuals. By virtue of equation (3.25), the theoretical quit rate holding sample size constant is decreasing in the wage because the higher the current wage the less likely that any future wage will fall below the reservation wage as a consequence of the positive auto correlation in the wage process implied by the model. By implication

$$\partial\phi(w,t)/\partial w = \sum_{n=0}^{\infty} [\partial q(w,n)/\partial w]\exp(-\eta t)(\eta t)^{n}/n! < 0. \tag{3.27}$$

Consistency with the other stylized fact, that the conditional quit rate falls given the wage, is not so easily demonstrated. Indeed, such an inference is not true for all wage rates and tenures. However, negative duration dependence is implied for those who remain on the job long enough. To establish these assertions, first note that equations (3.26) and (3.25) imply

$$(3.28a) \qquad \partial\phi(w,t)/\partial t = \eta \sum_{n=0}^{\infty} [q(w,n+1) - q(w,n)]\exp(-\eta t)(\eta t)^n/n!$$

where

$$(3.28b) \qquad q(w,n+1) - q(w,n) = \eta[G(w^*(n+2);\ w,n+1) - G(w^*(n+1);\ w,n+1)] + \eta[G(w^*(n+1);\ w,n+1) - G(w^*(n+1);\ w,n)].$$

The change in the quit rate attributable to an increase in the sample size is the sum of two effects corresponding to the two terms on the right side of (3.28b). The first term is the change due to the change in the reservation wage. Because $G(\cdot)$ is a distribution function and the reservation wage increases with the sample size, the effect is always positive but will diminish to zero as n becomes large as a consequence of the convergence of the reservation wage to rV. The second term is the change attributable to the decrease in the variance of the next wage induced by the increase in the sample size. Because $G(\cdot)$ is the normal distribution function, a decrease in variance reduces its value to the left of the mean and increases its value to the right. In other words, the second term is negative if and only if $w > w^*(n+1)$. Notice that this condition is always satisfied for wage rates larger than or equal to rV by virtue of (3.20). This fact and convergence of the reservation wage imply that the second negative effect exceeds the first positive effect in absolute value for sufficiently large n. Finally, since the weights on the changes in the conditional quit rate associate with larger value of n increase with tenure in the expression on the right side of (3.28a), the conditional hazard rate must exhibit negative duration dependence for all sufficiently large tenures. Conversely, if w is less than rV, then (3.20) implies that $w < w^*(n+1)$ for all large n. Consequently, even if the condition does not hold for small n, the fact that the weight in the average defined on the right side of (3.28b) on values of the difference associated with large sample sizes increases with t implies a negative duration effect for all large tenures. In sum,

$$(3.29) \qquad \partial\phi(w,t)/\partial t < (>)\ 0 \text{ for all large } t \text{ when } w > (<)\ rV.$$

A more intuitively meaningful way to express this result is as follows. After an initial period spent learning about productivity, the likelihood of separating from the job decreases with tenure for those who have proven relatively more productive and increases with tenure for those who have proven relatively less productive.

The conclusion (3.29) seems to be in conflict with Jovanovic's [1979a] assertion that the quit rate exhibits negative duration dependence for all large tenure values. This apparent inconsistency is resolved by realizing that his result pertains to the unconditional hazard rate, the theoretical quit rate for the entire subsample of workers who attain tenure t. Formally, the latter is the expectation of the conditional quit rate defined in equation (3.25) taken with respect to the joint distribution of wage rates and sample sizes given that the worker attains tenure t. Specifically,

$$(3.30) \qquad \phi(t) \equiv \sum_{n=0}^{\infty} \{\int q(w,n)dQ(w,n)\} \exp(-\eta t)(\eta t)^n/n!$$

There are two effects of an increase in tenure on the unconditional hazard.

$$\phi'(t) = \sum_{n=0}^{\infty} \{\int q(w,n+1)dQ(w,n+1) - \int q(w,n)dQ(w,n)\} \exp(-\eta t)(\eta t)^n/n!$$

$$= \sum_{n=0}^{\infty} \{\int [q(w,n+1) - q(w,n)]dQ(w,n+1)\} \exp(-\eta t)(\eta t)^n/n!$$

$$+ \sum_{n=0}^{\infty} \{\int q(w,n)dQ(w,n+1) - \int q(w,n)dQ(w,n)\} \exp(-\eta t)(\eta t)^n/n!.$$

The first is the direct effect on the conditional quit rate of an increase in the sample size averaged over the possible wage rates and sample sizes of worker's who have attained tenure t. As already noted, this effect is negative for w greater than or equal to rV and positive otherwise for large n. Because equations (3.20) and (3.21) imply that virtually every worker still on the job will have a wage in excess of rV for n sufficiently large and because n and t are positively correlated, the average will eventually become negative as t increases. The second effect is attributable to "unobserved heterogeneity" in the form of different wage rates that reflect differences in predicted productivity across workers on the job revealed through the learning process and the wage selection process induced by the separation decision. Since workers with lower wage rates but the same sample size quit more rapidly and since the fraction of workers earning higher wage rates rises with the sample size, this effect is negative for all t. In sum, $\phi'(t) < 0$ for all sufficiently large t.

In this review of Jovanovic's model, the fact that the learning about the job hypothesis offers an alternative to the on-the-job training explanation for the observation that wages earned rise with tenure has been emphasized.

Although rising productivity attributable to some form of on-the-job training may contribute to the phenomena as Mincer [1974] and others have long argued, no trend only uncertainty in productivity is needed. Furthermore, to the extent that learning of the outlined form takes place here, any empirical measure of the extent of wage growth overstates the return to on-the-job training. Any empirical attempt to test the learning about the job hypothesis and to measure its contribution to on-the-job wage growth must explicitly model the quit decision responsible for the implied selection in the sequence of wage observations. The papers by Flinn [1973] and Marshall [1983] represent ongoing empirical studies with this purpose.

C. Stochastic Models of Individual Work Histories

As we have seen, the original model of search unemployment and its extensions to labor turnover analysis have implications for a worker's labor force experiences. The original model can be used to derive implications for the distribution of completed spells of search unemployment and the distribution of post unemployment earnings. Analogously, the extensions have implications for the nature of the probability distribution over completed job spells lengths and the stochastic nature of time paths of earnings. However, so far the possibility that the worker may either lose his or her job or decide to leave active labor force participation has been ignored. When these possibilities are explicitly treated, the theory can be viewed as a stochastic description of a workers entire labor force participation history. Recent extensions of the theory in these directions is the topic of this section.

Labor economists and the popular press make constant reference to unemployment and participation rates. For a specified population, these statistics describe the distribution at some point in time of the population over three states — non-participation, employment, and unemployment. It has long been recognized that if movements among these states by like individuals can be described as a Markov chain, then this distribution converges over time to a steady state which can be completely characterized in terms of the probabilities per period that an individual in the population makes a transition from each to every other state. This model of individual worker histories is the basis for a considerable empirical literature which attempts to understand differences in participation and unemployment rates across populations by studying the differences in the transition probabilities that determine the steady state distribution of workers across states in the Markov model. For example, such an analysis demonstrates that the unemployment rate for young males is higher than that for their older counterparts because their transition probability from employment to unemployment is higher, not because their probability of transition from unemployment to employment is lower. In other words, short employment spells, not long unemployment spells are responsible for the difference.[15]

Of course, there is a close relationship between the search model and the Markov model of the labor force experience of an individual worker over time. In the original model of search unemployment, the probability of finding an acceptable job per period is the worker's probability of making the transition from unemployment to employment per period. In the extensions to turnover analysis, the quit probability per period is the probability of transiting from the worker's current job to a new one. Indeed, Jovanovic's matching theory and the other related work on the job shopping hypothesis provide explanation for why the job spell length are shorter for younger workers. The first rigorous and complete application of the relationship between search theory and the Markov chain model of individual worker histories is contained in a seminal but difficult paper by Lucas and Prescott [1974]. In the paper, the authors illustrate how the theory of job search can be used to develop a consistent "equilibrium" theory of the employment and labor turnover experience of the typical individual.

Extensions of this type of analysis to include the labor force participation and hours worked decisions are studied by Burdett and Mortensen [1978] and by Toikka [1976]. Subsequent theoretical contributions along these lines designed with empirical estimation in mind include papers by Burdett, et. al. [1982], Flinn and Heckman [1982b], Coleman [1983], and Mortensen and Neumann [1982], Lundberg [1984], and Weiner [1982]. Related papers that introduce "aggregate demand" disturbances into a similar theoretical structure include Lippman and McCall [1976b] and Jovanovic [1983]. All of these represent efforts on the research frontier. In this section, a variation on the Lucas and Prescott [1974] model and a simple extension of it is presented. Search unemployment and non-participation are distinguished as a means of introducing the principal ideas and structure that underlies the approach taken in this literature.

In the Lucas and Prescott [1974] formulation the distribution of wage offers represents productivity differentials across different locations (jobs or employers) at a point in time. The authors refer to the locations as "islands" populated at any moment by firms who can't move among islands and workers who can. On each island, wages are determined competitively, the wage offered is equal to the local marginal product of labor on each island. Hence, the distribution of productivity across islands induces a distribution of wage "offers" across the islands. Although communication among the islands is imperfect in the sense that each worker knows only the current wage on his or her own island, workers know that these differences exist and their extent as described by the wage offer distribution function. This knowledge motivates investment in search as a means of finding an island where labor is more highly rewarded than that currently occupied.

Of course, if the conditions that determine demand on each island were permanent and workers were identical in production, then the search process, even though imperfect, would eventually produce wage rate equalization either because all workers would end up on the island where productivity is highest or, under conditions of diminishing returns to labor, migration would distribute workers across islands in the manner required to equalize marginal productivity. However, it is more realistic to suppose the productivity on each island, though persistent to some extent, changes from time to time due to changes in weather say or to changing conditions of derived demand. In such an economy, individual workers are continually moving from one sector to another in pursuit of current wage gains.

At the aggregate level there are always workers who are not employed in such an economy. They are those who are currently on islands where labor productivity happens to be below the opportunity cost of working. However, the unemployed fraction reflects the search and mobility behavior of the workers. The "equilibrium" level of unemployment then depends on the characteristics of the process that generates changes in productivity on the islands, the technology by which workers receive information about alternative earning opportunities, and the motives that workers have to search. Finally, the model also implies that the workers earnings over his or her lifetime can be characterized as a well specified stochastic process.

Let us suppose that output on each island is produced subject to constant returns using labor as the only input. Output per worker over time, productivity, is assumed to be a stochastic process $\{x(t)\}$ on each island.

The productivity processes across islands are identical but independent. Specifically, the process on each is a Poisson arrival process with arrival rate α, which determines the stochastic arrival date of the next value of productivity, and a distribution $F(x)$ from which the next value is drawn. Hence, the process is Markov and F is its stationary distribution in the sense that future values of productivity conditional on the current value of the process converges to F as the future date increases independent of the current value. Furthermore, because productivity processes on other islands are identical and independent, the cross island distribution of productivity converges to F. In the sequel, we assume that the latter convergence has already taken place.

Let w denote the wage currently offered on a particular island. Given the technology and the competitive spot market assumption, w is the current productivity of labor on the island. Given the wage offered, each worker on the island must decide whether to be employed on the island now and/or whether to search for a higher wage elsewhere. For simplicity of exposition, we assume that the cost of search is the same whether employed or not but restrict the worker intensity of search choice to be either zero (no search) or one (search). Let b denote the opportunity cost of working, the output equivalent value of "leisure", and let c denote the cost of search in terms of output as before. When searching, the worker receives information about the wage and employment conditions on some other island with instantaneous probability λdt, where λ is the offer arrival rate. The alternative wage discovered is a random draw from F, the steady state distribution of wage offers across the islands. Upon the arrival of information about the wage offered on another island, the worker must simply decide whether to move to the other island or to stay on that currently occupied.[16]

Let $V(w)$ denote the worker's expected future wealth given an optimal strategy for choosing when to be employed, when to search, and when to move from one island to another where w is the wage paid on the island where the worker is currently occupied. Given the assumption that the cost of search is the same whether employed or not, the worker is currently employed if and only if the wage offered on the island, w, is at least as large as the value of leisure, b. Whether searching or not, the productivity or wage on the worker's current island may change exogenously. Given such a change, the worker reevaluates both the decision to be employed and the decision to search. If searching, there is a possibility of an arrival of information about employment conditions on another island. This event requires a decision to move or not. Of course, all decisions are made so as to maximize the expected future stream of net income with appropriate account taken of the output equivalent value of leisure. During a short interval of length dt, an exogenous change in the wage offered on the island occupied occurs with probability αdt and the new wage is a random draw x from the distribution F. The capital gain or loss associated with this event is the expectation of the difference $V(x) - V(w)$. If searching, an alternative wage offer x, also drawn from F, arrives with probability λdt during the short future interval of time dt. In this case the worker can choose between $V(x)$, the value of occupying the alternative island, and $V(w)$. In making these comparisons, the future decision to be employed and to search on both the home island and the alternative are assumed to be made optimally.

From this discussion, it follows that the imputed interest income on the worker's wealth given the optimal employment and search strategy can be written as

$$(3.31) \qquad rV(w) = \max_{s\varepsilon\{0,1\}} \{\max(w,b) - cs + \lambda s\int\{\max[V(w),V(x)]-V(w)\}dF(x)$$

$$+ \alpha\int[V(x) - V(w)dF(x)\} \text{ for all } w\varepsilon X.$$

The max(w,h) is the worker's current income given the optimal current employment decision. The last two terms on the right side of (3.31) are respectively the expected capital gains (or loss) associated with the arrival of information about the wage on another island and the arrival of a new wage on the worker's current island respectively. The existence and uniqueness of an optimal search strategy is equivalent to the existence and uniqueness of the value function $V:X\to R$ that solves the functional equation (3.31). One can verify that this condition is satisfied by showing that the mapping implicit in (3.31) satisfies Blackwell's [1965] sufficient conditions for a contraction.

It is intuitively obvious and easily demonstrated using the methods presented earlier that

$$(3.32) \qquad V(w) = V(b) \text{ for all } w < b \text{ and } V'(w) > 0 \text{ for all } w > b.$$

Of course V(b) is the worker's maximal expected wealth when not employed and V(w) for wage rates greater than or equal to the value of leisure is the worker's wealth when employed at such a wage. An implication of (3.32) is that the worker will move to another island only when the wage offered on the alternative x exceeds that on the island currently occupied. Therefore, the solution to the optimal search decision as defined on the right side of (3.31) is

$$s^*(w) = 1 \text{ if and only if } \lambda\int_w^\infty [V(z)-V(w)]dF(z) > c. \tag{3.33}$$

In other words, the worker searches, whether employed or not, if and only if the expected return given the wage currently available exceeds the cost. Since the return to search generally declines with the wage available, the optimal search rule satisfies the reservation property and the reservation wage w^* solves

$$\lambda\int_{w^*}^\infty [V(z) - V(w^*)]dF(z) = c$$

provided that $w^* > b$. Since in the no search region ($w > w^*$), equation (3.31) implies

$$V(z) - V(w^*) = \{\max[z,b] - \max[w^*,b]\}/(r+\alpha),$$

the search reservation wage is the unique solution to

$$\frac{\lambda}{r+\alpha}\int_{w^*}^\infty [z-w^*]dF(z) = c \tag{3.34}$$

which exceeds b if and only if the return to search when unemployed exceeds the cost, i.e.,

$$\frac{\lambda}{r+\alpha}\int_b^\infty [z-b)dF(z) > c. \tag{3.35}$$

Of course, if (3.35) is not satisfied, no one searches in the model.

Notice that the return to search is decreasing in the frequency with which productivity changes on every island, α. If differences in productivity across islands is purely transitory, which corresponds to the extreme case of $\alpha = \infty$, then there is no incentive to search.

A worker's earnings experience over time can be characterized as a Markov process $\{w(t)\}$ in this model, one defined on X the support of the wage offer distribution F. Let $P(w,t)$ denote the probability that the worker will be on an island that offers a wage less than or equal to w at some future date t. This sequence of c.d.f.s can be derived using procedures found in Feller [1957]. The heuristic argument that follows yields the same result. Think of $P(w,t)$ as the fraction of an identical population of workers who are on islands that offer w or less. Since workers only move voluntarily to islands offering a higher wage, the flow of workers into the class of islands offering w or less during the next instant is the exogenous flow of workers on islands whose productivity was larger than w but fell below during the instant. It equals $\alpha dtF(w)[1-P(w,t)]$, the product of the probability of an exogenous change in productivity on any island, the probability that the new value is less than or equal to w and the fraction of the population on islands at time t with wage in excess of w. The corresponding exogenous outflow of workers from the set of islands paying less than w is $\alpha dt[1-F(w)]P(w,t)$ for analogous reasons. Finally, the endogenous flow of workers leaving islands paying w or less is made up of those that are searching who obtain information about an island currently paying more than w. This flow is equal to $\lambda dt[1-F(w)]P(w,t)$ if $w < w^*$, since all workers on such islands are searching, and $\lambda dt[1-F(w)]P(w^*,t)$ otherwise, since only the fraction $P(w^*,t)$ of those on islands paying less than w are searching. Since the change in $P(w,t)$ in a time interval of length dt is simply the difference between the inflow and outflow during the interval, the instantaneous time rate of change is given by

$$dP(w,t)/dt = \alpha F(w)[1-P(w,t)]-(\alpha+\lambda)[1-F(w)]P(w,t) \text{ if } w < w^* \tag{3.36.a}$$

and

$$dP(w,t)/dt = \alpha F(w)[1-P(w,t)]-\alpha[1-F(w)]P(w,t)-\lambda[1-F(w)]P(w^*,t) \tag{3.36.b}$$

otherwise.

The stationary distribution associated with this birth and death process with state space X is

$$P^*(w,w^*) = \frac{\alpha F(w)}{\alpha+\lambda[1-F(w)]} \text{ for all } w < w^* \tag{3.37.a}$$

and

$$P^*(w,w^*) = F(w)-(\lambda/\alpha)[1-F(w)]P(w^*,w^*) \text{ for all } w > w^*. \tag{3.37.b}$$

Of course,

$$P^*(b,w^*) = \frac{\alpha F(b)}{\alpha+\lambda[1-F(b)]} \text{ provided that } w^* > b, \tag{3.38}$$

the steady state fraction of workers on islands with wage less than or equal to their common reservation wage, is also the steady state unemployment rate for the population.

An alternative direct method of deriving the steady state unemployment rate follows from the observation that each worker's employment experience can be viewed as Markov chain in continuous time defined on two states, employment and non-employment. If a non-employed worker searches, then the instantaneous transition rate from unemployment to employment is $(\lambda+\alpha)[1-F(b)]$ and the instantaneous transition rate from employment to unemployment is $\alpha F(b)$. The steady state probability of unemployment associated with such a chain is simply the latter transition rate divided by the sum of the two.

The steady state distribution of earning opportunities across a large sample of identical workers who set the common reservation wage w^* is $P^*(w,w^*)$. The c.d.f. also represents the fraction of each worker's future life when a wage opportunity less than or equal to w will be available given that the worker's reservation wage is w^*. Given the latter interpretation, the role of wage search and in particular the motive for setting the reservation wage can be clearly seen. The searching worker's earnings opportunities in the future are more favorable than the distribution of wage offers on a particular island in the future, which is F, in the sense that $P^*(w,w^*) < F(w)$. In other words, a higher wage is more probable and the degree to which it is more probable increases with the reservation wage, at least for $w > w^*$, when the worker seeks higher wage rates on the other islands.

Models of this type are called "two state" models of worker experience because the individual worker is either employed or not at any point in time. The non-employment state is search unemployment if condition (3.35) is satisfied and non-participation if it is not. Non-trivial "three-state" extensions of this type of model are presented in the papers by Burdett et.al. [1982], Flinn and Heckman [1982b], Coleman [1983], and Mortensen and Neumann [1982] and Jovanovic [1983]. The extension in all cases is obtained by supposing that a worker's value of leisure is subject to stochastic change over time. We illustrate the basic idea by extending the "island" model in this way along the specific lines contained in Coleman.

Assume that a worker's value of leisure is a stochastic process $\{b(t)\}$ of the now familiar type. New values arrive via a Poisson process with arrival rate β and each new value is a random draw from the stationary distribution of the process, G. The expected duration of any given value $1/\beta$ is a measure of persistence in the worker's value of leisure. The assumption motivates a non-trivial decision when not employed between search unemployment and non-participation, which is defined as the state of being neither employed nor searching. To extend the formal analysis we now need to represent the worker's maximal wealth as a function of both the current wage on the island occupied, w, and the worker's current value of leisure, b. Let $V(w,b)$ represent the function. Now, in addition to the possibility of an endogenously determined arrival of information about the wage paid on another island and an exogenous change in the wage paid on the worker's current home island, there is a possibility of an exogenous change in the worker's value of leisure. It occurs with probability βdt per period of length dt and yields a new wealth $V(w,y)$ where y is a random draw from G which has support Y. Given such a change, the worker must reevaluate both his employment and his search decision. The analogue to equation (3.31) in the extended model is

$$(3.39) \qquad rV(w,b) = \max_{s\epsilon\{0,1\}}\{\max(w,b)-cs+\lambda s\int\{\max[V(w,b),V(x,b)]-V(w,b)\}dF(x)$$

$$+ \alpha\int[V(x,b)-V(w,b)]dF(x) + \beta\int[V(w,y)-V(w,b)]dG(y)\}$$

$$\text{for all } (w,b)\epsilon X\times Y.$$

In this case,

(3.40) $V(w,b)$ is strictly increasing in both w and b everywhere

because the worker has the option of going to work at wage w in the near future were his value of leisure to fall sufficiently even if the wage is less than the current value of leisure.

As a consequence of (3.40), wealth on an alternative island $V(x,b)$ exceed that on the worker's home island $V(w,b)$ only if the wage offer x exceeds the home island wage w. Therefore, the worker's search strategy satisfies the reservation property but the current reservation wage is a function of the worker's current value of leisure which we denote as $w^*(b)$. The solution to the optimal decision to search or not defined on the left side of (3.39) implies that the contingent reservation wage equates the expected return and cost of search given the current value of leisure. Formally, it is the solution to

$$(3.41) \qquad \lambda\int_{w^*(b)}^{\infty} [V(z,b)-V(w^*(b),b)]dF(x) = c.$$

On the no search region $z > w^*(b)$, equation (9) implies

$$(3.42) \qquad (r+\alpha+\beta)\ [V(z,b)-V(w^*(b),b)] = \max(z,b)-\max(w^*(b),b) + \beta\int[V(z,y)-V(w^*(b),y)]dG(y).$$

By virtue of (3.41) and (3.42) the contingent reservation wage is independent of b when it is greater than or equal to b since $w^*(b) > b$ implies that the first term on the right side of (3.42) is $z-w^*(b)$ and the second term does not directly depend on b. However, when $w^*(b) < b$, then the first term is 0 for $z \leq b$ and $z - b$ otherwise on the region $z \geq b$. This fact and $V(w^*(b),y)$ increasing in its first argument imply that $w^*(b)$ is decreasing in b when $w^*(b) < b$. In sum, there exists a constant w^* and a strictly decreasing function $\gamma(b)$ such that

$$(3.43.a) \qquad w^*(b) = w^* \text{ for all } b \leq w^*$$

and

$$(3.43.b) \qquad w^*(b) = \gamma(b) < w^* \text{ for all } b > w^*.$$

Of course, the constant w^* corresponds to the reservation wage in the "two state" model. It is the wage at which the worker is indifferent to search given employment. The function $\gamma(b)$ determines when the worker searches given that he or she is not employed ($w<b$). If the wage is sufficiently small $w \leq \gamma(b)$, it pays to search but for wage rates on the current island satisfying $b > w > \gamma(b)$, the individual neither works nor searches. In this region, the worker waits instead for productivity on his own island to improve. The size of this region increases with the absolute value of the slope of the function $\gamma(b)$. Note that (3.41) and (3.42) implies that the magnitude of the slope increases as the frequency of change in the value of leisure β decreases. In the limit as β goes to zero, the slope tends to infinity. Of course, the limiting case is the "two state" model studied earlier.

The analysis above allows one to partition the space of wage and value of leisure pairs, $x \times Y$, into three worker labor force participation states --

employment, unemployed search, and non-participation. Denote these as E,U and N. Obviously, for this model these are

$$(3.44.a) \qquad E = \{(w,b) \varepsilon X \times Y \mid w \geq b\}$$

$$(3.44.b) \qquad U = \{(w,b) \varepsilon X \times Y \mid w < \min[b, \gamma(b)]\}$$

$$(3.44.c) \qquad N = \{(w,b) \varepsilon X \times Y \mid b > w \geq \gamma(b)\}.$$

The significance of these states is obvious. If the worker's current employment opportunity as characterized by the wage on the island occupied and current value of leisure pair lies in E, then employment is preferred. When the pair is in U, the worker chooses to search while unemployed and, when in N, the worker is neither employed nor searching.

Unfortunately, a worker's labor market experience through time cannot be characterized as a simple three state Markov chain as was true in the two state version because transitions to and from each of the states depend on the worker's current wage and value of leisure pair. However, it is true that the worker's optimal employment-search strategy induces a stochastic process that characterizes future time paths of the worker's earnings opportunities and values of leisure pairs which is Markov on the state space X×Y. Indeed it is a two dimensional birth-death process extension of the one dimensional process analyzed earlier. That process has a stationary distribution which depends on the search reservation wage. Using that distribution one can solve in principle for the unemployment and participation rates implied by the model as we did for the unemployment rate in the two state version.

Jovanovic [1983] incorporates "aggregate" productivity disturbances into the two state version. Essentially his innovation is to view the wage offered at any island as the product of a local and an aggregate productivity component

(3.45) $\quad w = xy$

where the local component x is generated by a different but identical Markov process on each island and the aggregate component y is generated by a single process which is of course the same for all islands. Were one to view $\{x(t)\}$ as a continuous time jump process with arrival rate α and stationary distribution F which is the independent but identical across islands and $\{y(t)\}$ as the same process on all islands characterized by an arrival rate β and stationary distributioon G, one could easily use the apparatus constructed in this section to analyze a model along the lines that he suggests. Interestingly, one obtains a non-trivial three state model of worker experience in this case as well because when the local component of productivity is relatively high and the aggregate component is low it pays to wait for aggregate conditions to improve rather than search when unemployed. Jovanovic interprets this third state as laid off rather than not-participating with some justification. To the extent that ups and downs in the aggregate productivity component can be interpreted as business cycle variations, the model is consistent with the often observed fact that quits are procyclic and layoffs are countercyclic.

The models of the type reviewed in this section are theoretically primitive on the one hand and extremely difficult to empirically estimate and test on the other. Nevertheless, they offer and exemplify a framework capable of producing many suggestive hypotheses about the responses that individual's make to their every changing work and household environment. There is much room for future research. The identification of the important factors that induce changes in the individual's decision to work and to participate is an open empirical question. Were more known about them and the processes generating changes in them, then the effects of a more realistic analysis of worker response to change and its effect on observed worker histories is possible. The second area for important research is the development of appropriate econometric techniques for estimating and testing models of this type using panel data. One of the obvious problems for estimation is unobservables. Specifically, what does the econometrician use as a measure of either the "wage available" in the case of an unemployed worker or the "current value of leisure" in the models outlined in the section? Are there ways around this problem of incomplete observation or will serious empirical work have to wait for better data?

IV. Search Equilibrium and the Efficiency of Unemployment

What does an equilibrium in the labor market look like when worker information about employment opportunities is imperfect and costly? Will an equilibrium under these conditions possess any properties of social optimality? The purpose of this section is to present answers to these questions reported since Rothschild [1973] first seriously raised them.

There are two pertinent existing branches of the literature and a third that seems to be emerging. The first is motivated by Rothschild's question, what is the source of the price dispersion that motivates search? It focuses on the equilibria of pricing games in markets where a well defined homogeneous good is exchanged populated by many price setters who take the prices set by others as given but anticipate the responses of price takers to their own offers and price takers who take the menu of offers as given but search optimally among them as though they knew not who offered which price. The questions in this branch concern conditions for the existence of price dispersion for a homogeneous good. When does the competitive "law of one price" hold? The second branch of the literature, at least its labor economics component, view the source of wage dispersion as job and match specific variations in productivity. The authors ask, are the investments in search that individual workers make socially optimal? Or, in the more provocative language that Prescott [1975] uses, is the "natural rate" of unemployment efficient? The emerging third branch deals with some of the same issues but within the implicit labor contract framework. One of the questions here is whether externalities identified in the second branch of the literature might not be internalized when employers compete by forming reputations concerning their respective wage, recruiting, and layoff policies.

The analysis presented in this section focuses on several specific examples of results found in the second literature for three reasons. First, results presented in the pricing game literature suggest that the single price assumption for a homogeneous good imposes restrictions on the search technology that are not all that severe. In short, were there no real variation in the value of the productivity of an identifiable class of workers across jobs, search theoretic ideas would contribute little to our understanding of the labor market experience of the typical individual in the class. Second, the subject of the second branch of the literature is more pertinent to the field of labor economics. Finally, the budding third branch is better discussed later as a topic for future research. Nevertheless, a short overview of the price setting literature seems appropriate as a preliminary to the main event, if for no other reason than to provide a justification for the author's design of this essay.

The literature on the social efficiency of search investment begins with speculation by Phelps [1972], Tobin [1972] and others before them on the existence of congestion effects in the search process. Given the flow of opening, any unemployed individual's probability of finding one is likely to be lower the larger the stock of unemployed, they argue. These author's suggest that the unemployment rate is too high as a consequence. Hall [1972] characterizes the "reserve army" of the unemployed as a common resource which is over utilized by the host of employers that recruit from it with no regard to the impact of their behavior on the other users. In his formal version of the argument, Hall [1976] shows that the result is too little unemployment. The ideas reviewed in this section are derivative of the claim by Lucas and Prescott [1974] that their "island" model of search equilibrium is characterized by an efficient unemployment rate. In their paper and those to be reviewed, worker movements into and out of employment is explicitly specified as a stochastic process generated by an exogeneous productivity process and worker search. Agents make individually optimal choices with expectations that are rational in the sense that decision-relevant future events in the economy are expected to occur with probability distributions generated by the model. The long run outcome is characterized by a statistical balance of the flow of workers into and out of unemployment. "Equilibrium" unemployment is the corresponding steady state stock. The Lucas and Presoctt claim for efficiency is the consequence of the fact that there are no external effects present in their model that have an impact on decisions that affect the steady state stock of the unemployed. Such is not the case in the other work reviewed.

Three externalities arising out of different specification assumptions within a model of the general Lucas and Prescott type are entertained. The first specification, due to Diamond [1981], is in a sense Hall's "spare tire" theory of unemployment with the roles of the common resource user and common resource now being played by the worker and vacancies respectively. The result is analogous. Over utilization implies too few vacancies and, given a fixed number of jobs, too little unemployment. That the searching worker's probability of obtaining information about a job opening is proportional to the vacancy rate is the crucial assumption, valid when the total number of jobs is given and workers search among them at random. Since the vacancy rate declines with the number of workers employed, given a fixed number of jobs, the steady state vacancy rate and with it the welfare of a particular worker increases with the reservation wage chosen by others. Hence, all benefit if all were to raise their reservation wage rates above the equilibrium values because none takes account of the fact that his or her own acceptance decision adversely affects the probability that another will find an opening.

The second effect, pointed out by Jovanovic [1983], can be viewed as a version of musical chairs. Jovanovic imagines that worker productivities across jobs differ but are identical for different workers in the same job. Consequently, it doesn't matter from a social efficiency point of view who is in which job. Indeed no one would search in a steady state once the jobs were filled if each were of infinite duration. However, under the assumption that jobs have random finite durations but each one that dies is immediately replaced by a twin somewhere else in the economy, workers who lose their jobs from time to time are motivated to set their reservation wage rates too high by the prospective of distributive private gains. The equilibrium unemployment rate is too high, at least when search only by unemployed workers is assumed.

In the third specification, versions of which were formulated independently by Mortensen [1982a, 1982b] and Pissarides [1984], productivity is match specific and revealed only when worker meets job. Wage determination is viewed as a bilateral bargaining process engaged in by each potential pair as they meet. The employer's and worker's reservation wage rates, which reflect respectively the value of the opportunity that each has to seek an alternative trading partner, appropriately serve as the "threat or no trade" point in the negotiations. Trade takes place only when the maximum wage that the employer will pay is no less than the minimum that the worker will accept. Presumably, when a surplus exists, they agree to split the difference. But, if such is known to be the bargaining outcome for all possible future job-worker pairs, neither the searching worker nor the recruiting employer takes account of the share of the surplus that their future match mate will enjoy when allocating resources that affect the probability of the meeting. Given that only unmatched agents search at a constant intensity, workers set their reservation wage too low and employers set theirs too high. Consequently, the steady state employment rate is too high. However, if search while matched is feasible and search effort is chosen at a cost, the result is reversed because the private return to search effort is less than the public and because the equilibrium unemployment is inversely related to search effort.

A. Equilibrium Price Dispersion

The story begins with Diamond's [1971] astute observation that there can be no wage dispersion in the equilibrium of a game where employers set wage offers with knowledge of worker search strategies, workers are equally productive with certainty in every job, workers search randomly, sequentially, and without recall among the offers regarded as given, and workers face a positive cost of search. The argument is a simple one. Under these conditions, the stopping wage of every worker is less than the highest wage offer of a disperse distribution whether workers search while employed or not. Therefore, the employer offering such a wage can lower it without affecting either the acceptance decisions of potential employees or the quit decisions of existing ones. Furthermore, for the case of search by unemployed worker's only and workers who are all assumed to have the same value of leisure, which is the case that Diamond considers, the common market wage must equal that just required to induce participation, the value of leisure plus the carrying cost on the search investment required to find the first opening. This conclusion follows from the fact that were a common wage offered in the market, the workers' common reservation wage lies between the offer and the wage required for participation. Notice, however, that the equilibrium market wage is not the "competitive equilibrium" wage in general. Instead, it is the discriminating monopsony wage, that which leaves the workers no surplus, no matter what the demand conditions may be. The problem here is that it does not pay to search if only a single employer out of a host offers an alternative to the equilibrium because no worker knows where the employer is.

Diamond's contribution elicited a flurry of responses, two of the best are by Butters [1977] and Wilde [1977]. As Butters observes, a deviant employer has the incentive to advertise to workers where the firm is located if the firm's marginal product of labor exceeds the Diamond equilibrium wage. He then constructs an advertising technology that randomly distributes messages containing both wage offer and location information among the workers at a cost. The result is a non-degenerate equilibrium wage offer distribution. Wilde obtains the same result without a change in the basic information transfer structure by supposing that a random number of different wage offers arrive per period. Within the period, the worker can respond to the highest. In a more recent contribution by Burdett and Judd [1983], the following general characterization is established. If workers receive no more than one offer per period in a sequential search, no recall, discrete time framework, then Diamond's result obtains. If all receive more than one with a positive probability, then a non-degenerate equilibrium wage offer distribution exists with support bounded from above by the value of marginal productivity. Finally, if all workers receive two or more offers per period with probability one, then the only equilibrium distribution is degenerate at the "competitive" wage, i.e., the value of marginal productivity. In short, little price comparison is required to guarantee that the competitive "law of one price" is valid.

Still there is an important information externality implicit in this structure. To make it explicit, suppose that each worker can choose between exactly one or two random wage quotations per period at a cost. If the marginal cost of the second quote is sufficiently small, it would be in the collective interest of all workers for all to purchase two wage quotes since then the common wage offer would equal the common productivity of all the worker's with probability one. However, this outcome is not a non-cooperative equlibrium in the game theoretic sense because when no wage dispersion exists, no individual worker has an incentive to purchase the second wage quote. In this case, Burdett and Judd [1983] establish that a Diamond equilibrium always exists and that multiple non-degenerate equilibria wage offer distributions may exist. The point here is that an individual worker benefits from the investment in search made by others because the nature of the equilibrium depends on their aggregate investment.[17]

B. Equilibrium Unemployment and Social Efficiency

For the purposes of forging a simple tool that can be used to illustrate when the equilibrium extent of worker search is and is not socially efficient under the different conditions considered in the literature, it is convenient to think in terms of the following variation on the island theme. In this section, the jobs on any specific island have an uncertain but finite length of life simply described by an exponential distribution with death rate δ. One might think of the distribution as that of the life times of industries, as the distribution of the lengths of time a certain occupation or trade within an industry is useful, or as simply as the random lengths of time required to get a specific job done. Although this distribution can be assumed to take a different functional form and may be in some larger sense endogenous to the economic environment, for the purpose of the illustrations contained here, generalizations of this type matter little. Next, assume that the number of islands where jobs are offered is none the less constant over time. Those that die on one day are replaced by others elsewhere. However, the workers on the islands that disappear must move to some other in order to find employment. The third assumption maintained throughout the section is that only unemployed workers search and they do so at a constant search intensity. It is this assumption which is common to the literature and which unfortunately implies that the extent of aggregate investment in search can be measured by the fraction of the labor force not employed. We will attempt to point out how the interpretation of results might change were a more general specification of the search technology allowed. Finally, workers do not discount the future and, therefore, care only about average lifetime net income per period. This last assumption allows one to phrase the social efficiency question in the following terms. Does the amount of search investment determined by the choices of individual workers in response to private motives maximize "steady state" net income per worker? Again, this is just a simplifying devise. However, without it one has to go through the motions of solving a rather tedious dynamic social welfare problem, that of maximizing aggregate wealth, with very little return in terms of insight per word written on paper.

In our new island economy peopled by infinitely lived workers, those that are unemployed have lost their jobs for "structural" reasons. They are all seeking new locations on some other island — job or industry. As we shall see, the answer to the social efficiency question depends on the interpretation one gives to the wage offer distribution. In this section, the dispersion in wage offers is regarded as a reflection of differences in any worker's job specific productivity at every island. Ex ante, every island is identical from the worker's point of view and every worker appears identical from the employer's. Ex post, as in Jovanovic's [1979] model, a specific worker-job productivity is realized as a draw from the match specific productivity distribution, the same distribution for every worker on every island. However, the samples drawn are independent across islands. Once realized, the worker is offered employment at wage equal to the revealed productivity.

Let $F(w)$ denote the common distribution of match specific productivities or wage offers on every island that is willing to employ workers. Let b denote the common value in output terms that workers place on leisure, c the cost of search in terms of output which is born only when a worker chooses to search, and λ the offer arrival rate when searching. By assumption, offers arrive continually via a Poisson arrival process with frequency λ. A worker's search strategy then is a stopping rule $s(w)$, a function with range equal to the support of the wage offer distribution F and domain equal to either zero, stop, or unity, continue. Only unemployed workers search. Finally, a worker's search strategy maximizes average net income per period over the indefinite future, hereafter referred to as average lifetime income. That strategy will possess the reservation property, i.e., $s(w) = 0$ if and only if $w > w^*$. Hence, the only choice to be made is w^*, the value of the worker's reservation wage.

Let $P(w,w^*)$ denote the steady state distribution of future employment opportunities at wage less than or equal to w that the worker will face over his life time given that his reservation wage is w^* where $w = 0$ corresponds to the event of being on an island whose employment opportunities have ended. Because such islands "disappear" but the location of the new islands that replace them are not known to the current occupants, the former are not sampled by searching workers while the latter are no more likely to be found than those already in existence. Under this assumption, the assumption that a worker's productivity in a given job is permanent so long as it lasts and the fact that the worker when searching migrates only to islands where he or she is more productive, the probability of employment at a wage less than or equal to w at the end of the next instant given that the worker's current offer exceeds w is simply δdt, the probability that the worker's current job ends during the next instant. However, if currently offered employment at a wage less than or equal to w, the probability of employment at a wage that exceeds w at the end of the next short time interval of length dt is $\lambda dt[1-F(w)]$ if and only if the worker is searching. Hence, the instantaneous time rate of change in $P(\cdot)$ is

$$(4.1a)\qquad dP(w,w^*)/dt = \delta[1-P(w,w^*)] - \lambda[1-F(w)]P[(w,\overset{*}{w}\,) \text{ if } w < \overset{*}{w}$$

and

$$(4.1b)\qquad dP(w,w^*)/dt = \delta[1-P(w,w^*)] - \lambda[1-F(w)]P(w^*,w^*) \text{ otherwise.}$$

Because in the steady state, the former probabilistic "inflow" must balance the probabilistic "outflow" by definition, the steady state distribution, given that the worker's reservation wage is w^*, associated with this birth and death process is

$$(4.2a)\qquad P(w,w^*) = \delta/[\delta+\lambda[1-F(w)]] \text{ if } w < w^*$$

and

$$(4.2b) \qquad P(w,w^*) = 1 - (\lambda/\delta)[1-F(w)]P(w^*,w^*) \text{ otherwise.}$$

The steady state distribution describes the fraction of the indefinite future that a worker who chooses reservation wage w^* will spend on islands where employment is possible at a wage less than or equal to any given value w. Of course, more search as signalled by a larger reservation wage implies a more favorable lifetime distribution of employment opportunities in the stochastic dominance sense, i.e., $P(w,w^*)$ is decreasing in w^* for fixed w, at least for values of $w > w^*$. The fraction of the future that the worker will spend unemployed and searching is given by $P(w^*,w^*)$, the steady state probability of being on an island where the wage is less than his or her reservation wage. Notice that if $w^* = 0$, the worker never searches, then $P(0,0) = 0$ because eventually jobs on his island disappear.

The worker chooses the reservation wage to maximize own average lifetime income which is defined by

$$(4.3) \qquad y(w^*) = (b-c)P(w^*,w^*) + \int_{w^*}^{\infty} w dP(w,w^*).$$

Since equation (4.2b) implies that average lifetime income as expressed in equation (4.3) can be rewritten as

$$(4.4) \qquad y(w^*) = [\delta(b-c)+\lambda \int_{w^*}^{\infty} w dF(w)]/[\delta+\lambda[1-F(w^*)]],$$

an interior solution satisfies

$$y'(w^*) = \lambda F'(w^*)[y(w^*)-w^*]/[\delta+\lambda[1-F(w^*)] = 0.$$

Consequently, the reservation wage is the maximal average lifetime income per period and solves

$$(4.5) \qquad w^* = b-c + (\lambda/\delta) \int_{w^*}^{\infty} [w-w^*]dF(w)$$

if and only if the worker participates ($w^* > b$) which is equivalent to the condition

$$(4.6) \qquad (\lambda/\delta) \int_{b}^{\infty} [w-b]dF(w) > c.$$

Notice that equation (4.5) is equivalent to the reservation wage equation in the standard model except that δ the probabilistic rate at which any job dies replaces the interest rate. It is in this model the "depreciation rate" applied to the stream of future returns attributable to current search for the next acceptable job.

The social efficiency of the private reservation wage follows by virtue of a simple argument. Since all workers are alike, $P(w,w^*)$ is not only the distribution of a worker's future life over employment opportunities, it also describes the steady state distribution of workers over employment opportunities at a point in time. Hence, the average lifetime income maximization problem is equivalent to the problem of choosing the common reservation wage of all workers to maximize average net steady state output per worker at every date. The resulting socially efficient equilibrium unemployment rate is $P(w^*,w^*)$ where w^* is that chosen privately by each worker. This conclusion would be no different were we to generalize the search technology by allowing a variable search intensity and search on the job in this particular formulation. The argument presented here follows that of Lucas and Prescott [1974], Prescott [1975], and Mortensen [1976]. The different types of search externalities whose presence imply that the two problems are not equivalent are introduced in the subsequent sections.

C. Vacancies as a Common Resource

In the model presented above, every island was assumed to be able to hire any number of worker's at their own realized match specific productivity. In other words, output is produced under constant returns to scale or equivalently, the derived demand for labor on each island is infinitely elastic. If production were subject to diminishing returns instead, a worker arriving early deprives a later arrival of an employment opportunity at a wage that would be otherwise higher and possibly precludes the latter from a job altogether.

Said another way, suppose the number of jobs on each island at any realized productivity is given and finite, an extreme form of diminishing returns. At any moment in time some of these jobs are open or vacant, others are not. If searching workers don't know where the vacant jobs are and consequently simply search randomly among the islands, then an individual worker's return to search depends on the vacancy rate. However, the steady state vacancy rate is endogenously determined, given the fixed number of jobs assumption, by the acceptance decisions of the other searching workers. An external effect exists. The higher that others set their reservation wage, the higher the vacancy rate, and the higher is the average lifetime income for the individual in question. In short, all benefit from an increase in the common reservation wage. The first formal analysis of the consequences of this external effect is contained in Diamond [1981]. The exposition that follows is based on ideas presented in that paper.

To make the point, one only needs to assume that the number of jobs is fixed on each island. Suppose for simplicity that there is only one per island. In the aggregate some fraction will be filled and that fraction is a constant in the steady state. Let v denote the steady state fraction of jobs that are vacant. An individual unemployed worker does not know where the vacancies are by assumption and consequently searches randomly among the islands with recognition of the fact that a visit to any one of them will yield an offer with probability v. In other words, each worker anticipates that offers will arrive at rate λv, the product of the frequency of message arrivals from other islands and the probability that the information received communicates that the island in question indeed has an opening. Under these conditions, the distribution of employment opportunities the worker faces over the future given his reservation wage w^* and the vacancy rate v is

$$P(w,w^*,v) = \delta/(\delta+\lambda v)[1-F(w]) \text{ if } w < w^* \tag{4.7a}$$

and

$$P(w,w^*,v) = 1 - (\lambda v/\delta)[1-F(w)]P(w^*,w^*) \text{ otherwise} \tag{4.7b}$$

by virtue of the argument used to derive the equations of (4.2). Note that an increase in the vacancy rate, ceteris paribus, improves the distribution, $P(\cdot)$ is decreasing in v.

The worker chooses his reservation wage to maximize lifetime average income as defined in equation (4.3) but now with the specification given in

(4.7) of the lifetime distribution of employment opportunities. Hence, his choice solves

(4.8) $$w^* = b-c + (\lambda v/\delta) \int_{w^*}^{\infty} [w-w^*]dF(x)$$

provided that the solution exceeds b, the participation condition is satisfied. Of course, the chosen w^* for an individual increases with v because an increase in the vacancy rate increases the return to search. To close the model, one may assume, with no loss of generality but considerable gain in notational simplicity, that the number of jobs in the economy is just equal to the number of workers. Hence, in a steady state the vacancy and unemployment rates are equal, i.e.,

(4.9) $$v = P(w^*,w^*,v) = \delta/(\delta+\lambda v[1-F(w^*)]).$$

A search equilibrium is a reservation wage and vacancy rate pair that simultaneously satisfies equations (4.8) and (4.9).

Since equation (4.9) implicitly defines the vacancy rate as an increasing function of the reservation wage, which we denote as

(4.10) $$v = f(w^*) \text{ where } 0 < f(\cdot) < 1,\ f'(\cdot) > 0,$$

while equation (4.8) also implies an increasing relationship between the two, the reader can verify that multiple equilibria may exist. But, of course, the important point is that no individual worker takes account of the fact that his choice of a reservation wage affects the vacancy rate that others face. A social planner recognizing this feature of the economy would choose the socially optimal reservation wage w^o to maximize average steady state net income per worker defined as

$$(4.11) \qquad y(w^o) = [\delta(b-c) + \lambda f(w^o) \int_{w^o}^{\infty} w dF(w)]/[\delta+\lambda f(w^o)[1-F(w^o)]],$$

the analogue to equation (4.4) in this case. The necessary first order condition for an optimal social choice is

$$(4.12) \qquad y'(w^o) = \lambda F'(w^o)[y(w^o)-w^o]/[\delta+\lambda f(w^o)\{1-F(w^o)\}] + \lambda f'(w^o) \int_{w^o}^{\infty} w dF(w)]/[\delta+\lambda f(w^o)[1-F(w^o)]] - \lambda f'(w^o)[1-F(w^o)]y(w^o)/[\delta+\lambda f(w^o)[1-F(w^o)]] = 0.$$

As the first term is zero at the private choice w^*, i.e., $w^* = y(w^*)$, we have

$$(4.13) \qquad y'(w^*) = \lambda f'(w^*) \int_{w^*}^{\infty}[w-w^*]dF(w)/[\delta+\lambda f(w^*)[1-F(w^*)]] > 0$$

i.e., a larger reservation wage than any equilibrium value will increase the average lifetime net output of all the workers. Furthermore, since the equilibrium unemployment rate is increasing in the reservation wage, it is "too small". There is not enough search unemployment in this economy because no searching worker takes account of his or her acceptance decision on the vacancy rate that others will face!

The existence of Diamond's externality depends critically on the interpretation of the information arrival process. The specific description of the process given above suggests that the worker randomly makes inquiries among the island regarding whether or not there is an opening and, if so, what the wage would be. This is the standard "search story". Suppose instead that the data are supplied by an information service that provides a continual flow of job listings such as the want ads of a newspaper or an employment agency. The cost of search might be interpreted as the cost of subscribing to the service. In this case, if the listing is only composed of vacant jobs and the information is up to date in the sense that the jobs listed are in fact open when the information arrives, then the externality doesn't exist. The results would be precisely the same as in the original model even when the number of jobs on each island is fixed, provided in the aggregate there are always vacant jobs available.[18] The argument in this section implies that this alternative information transfer mechanism is socially preferred to the random do-it-yourself sampling process, at least at the same average cost per vacant listing, because it eliminates the externality implicit in the latter process. It also suggests the need to model the process by which firms recruit and specifically how they advertise their openings. Of course, the externality reappears in a job advertising model if out of date listings circulate since the vacancy associated with a dated ad may already be filled when the worker responds to it.

D. Search as Musical Chairs

Recently, Jovanovic [1983] has suggested the possible existence of another type of search externality, one which shares features with the well known children's game. In this model, the wage offer distribution function F represents the distribution of fixed productivities across a given number of jobs or islands. All workers are equally qualified to perform each of these jobs, i.e., productivity is island or job specific not match specific. In the standard perfectly competitive full information model, $1-F(w)$ would simply constitute the market demand function in this case and the equilibrium wage and employment would be at the intersection with the supply schedule. Instead, workers are uncertain about which jobs offer which wage and jobs die at the exponential rate δ as before. Obviously, there are a limited number of jobs available associated with each wage offer; assume one per island with the aggregate number just equal to the the number of participants for simplicity. Finally, to distinguish the externality that arises in this case from the Diamond's, let us suppose that unemployed workers only receive information about jobs that are in fact vacant.

The nature of the externality is already quite obvious given the assumption that the wage offered on each island is simply marginal productivity on that island. There is no social gain associated with having one worker rather than any other in a particular job but there is a private incentive on the part of each to be first in finding the highest paying job. The private incentive to search exceeds the public and there is "too much" search unemployment given the standard model where only the unemployed search.

Again, let $P(w,w^*)$ represent the lifetime distribution of employment opportunities available to a worker given search only when unemployed using the stopping wage w^*. In deriving this distribution, remember that the worker only receives information about the vacant jobs but many of these are going to be jobs that were rejected by other workers. In other words, the sample of vacancies will not be representative of the population of jobs; it will be less favorable because others have picked them over. Indeed, in the steady state each individual is looking for the new "representative" sample of islands that have been born in place of those that have just died. Because of this adverse selection process and the assumption that the worker only receives information about vacancies, we need to characterize the wage offer distribution for vacant jobs before we can derive P, the distribution of employment opportunities over an individual worker's lifetime.

Let $F_1(w,w^*)$ denote the fraction of islands where both a vacancy exists and the wage offer is less than or equal to w given that all workers use w^* as their reservation wage and let $F_2(w,w^*)$ denote its complement so that

$$(4.14) \qquad F(w) \equiv F_1(w,w^*) + F_2(w,w^*) \text{ for all } (w,w^*).$$

Since no one accepts an offer below the common reservation wage by definition and job deaths are just matched by births in this wage category,

$$(4.15) \qquad F_1(w,w^*) = F(w) \text{ for all } w < w^*.$$

Now, each worker is receiving information about vacant jobs at arrival rate λ and by assumption there is one unemployed worker per vacancy. These assumptions imply that the instantaneous flow of workers who are informed about any vacancy per period is λ. Hence, the product of λ and the fraction of jobs that offer a wage less than w but greater than or equal to the common reservation wage, $F_1(w,w^*) - F(w^*,w^*)$, is the instantaneous rate at which jobs in this wage category are filled. To keep the fraction $F_1(w,w^*)$ constant for every w, this inflow into the set of jobs that are filled and offer less than w must just balance the deaths of filled jobs that pay less than w since no workers quit. In short, the steady state condition requires

$$\lambda[F_1(w,w^*) - F_1(w^*,w^*)] = \delta F_2(w,w^*) \text{ for all } w > w^*.$$

Hence, by virtue of, (4.14), (4.15)

$$(4.16) \qquad F_1(w,w^*) = [\delta F(w) + \lambda F(w^*)]/[\delta+\lambda] \text{ for all } w > w^*.$$

In other words, the steady state fraction is a mixture of the fraction of newly born jobs that pay less than w and the fraction of all jobs that pay less than the common reservation wage where the relative weight on the latter increases with the information arrival rate relative to the death rate. If no jobs die or information flows are instantaneous, then none of the vacancies are acceptable in the steady state.

The individual worker perceives the conditional distribution of wage offers over vacant jobs to be.

$$(4.17) \qquad G(w) = F_1(w,w^*)/F_1(\infty,w^*)$$

where $F_1(\infty,w^*)$ is of course the fraction of all jobs that are vacant. The individual worker's choice of reservation wage doesn't effect G, which is the reason for dropping w^* as an argument in the analysis of the decision problem. Indeed, a worker's lifetime distribution of employment opportunities is precisely analogous to equation (4.2) with G replacing F. Therefore, the reservation

$$(4.18) \qquad w^* = b-c + (\lambda/\delta) \int_{w^*}^{\infty} [w-w^*]dG(w),$$

the analogue of equation (4.5), if the worker participates ($w^* > b$). An equilibrium in this economy is a pair composed of a reservation wage w^* and a vacant job wage offer distribution G that simultaneously satisfy (4.17) and (4.18). To find an equilibrium, simply substitute for G in (4.18) from (4.17) in order to obtain the expression

$$w^* = b-c + (\lambda/\delta) \int_{w^*}^{\infty} [w-w^*]dF(w)/[\delta F(\infty) + \lambda F(w^*)]$$

$$= b-c + (\lambda/[\delta+\lambda F(w^*)]) \int_{w^*}^{\infty} [w-w^*]F(w).$$

Hence, if all jobs compensated for lost leisure, $F(b) = 0$, worker's participate under the same condition as in the original model (see equation (4.6)). Furthermore, the equilibrium is unique.

From each individual worker's point of view, the others pollute the set of vacant jobs by leaving those that are unacceptable. Each would benefit if the others were to increase their reservation wage leaving for him or her more acceptable vacant jobs. But, all cannot benefit by increasing their acceptance criterion. The game is a variation on musical chairs! Since $F_1(\infty)$ is both the unemployment rate and the vacancy rate and since $F_2(w)$ is the fraction of both jobs that are filled and pay less than w and workers that are employed and are paid less than w in the steady state by construction, the average income per worker per period given that all used the stopping wage w^o is

$$(4.19) \qquad y(w^0) = (b-c)F_1(\infty,w^0) + \int_{w^0}^{\infty} wdF_2(w,w^0)$$

$$= [(b-c)(\delta+\lambda F(w^0)) + \lambda\int_{w^0}^{\infty} wdF(w)]/[\delta+\lambda].$$

by virtue of equations (4.16) and (4.17). But, then the socially optimal reservation wage, the solution to

$$(4.20) \qquad y'(w^0) = \lambda F(w^0)(b-c-w^0)/(\delta+\lambda) = 0,$$

is simply the value of leisure less the cost of search. In short, there is no social return to search other than that required to find a job that compensates for foregone leisure. The rest of the private return is motivated by distributional gains. Since $w^* > b-c$ by virtue of (4.18), the equilibrium unemployment rate,

$$(4.21) \qquad P(w^*,w^*) = F(\infty,w^*) = [\delta+\lambda F(w^*)]/[\delta+\lambda],$$

is "too high".

E. Wage Bargaining and Search

A realistic view of the organization of the labor market suggests that every employer is an island. If so, then the assumption that the wage offer equals marginal product is questionable. In this subsection, we consider the consequences of a price determination model that is different from either the pricing game literature reviewed earlier or the simple idea that every island is a Walrasian spot market.

The alternative idea expressed in papers by Mortensen [1982] and by Diamond [1981] is that price determination in a search market context might appropriately be viewed as a bilateral bargaining problem. A "market" at any date in a world where it is costly to find trading partners is typically composed of a single seller negotiating with a single buyer. Of course, each has the option of looking for an alternative, but finding one requires time and resources by construction. The option of not trading and the costs and returns of pursuing that option determine for each agent a "threat" or reservation price, a minimal ask price for the seller and a maximal acceptance price for the buyer. If the latter exceeds the former, a bargain will be struck but the actual outcome is indeterminate. How the surplus is divided requires a detailed bargaining theory but is not really the concern here. Whatever the sharing rule, its nature will affect the returns to search of each individual on both sides of the market and, hence, the reservation prices that affect the outcome of every negotiation. An equilibrium for such a market populated by ex ante identical buyers and sellers whose values of exchange are uncertain for each pair until they meet is a specific bargaining outcome rule which determines how the surplus associated with each actual match is divided and an associated individually rational reservation price pair which defines the surplus for each match.

The bottom line in our context is that the wage received by any worker involved in a match is positively related to but less than the match specific productivity. Consequently, the private return to search is less than the social return which implies that there will be "too little" unemployment given the standard stopping model of search unemployment. The surplus that any subsequently met employer would receive were the worker to reject a marginal match now is ignored in the worker's reservation wage calculus. Hence, in the aggregate net output per worker increases given a marginal increase in the common worker reservation wage.

Specifically, let us return to the original model where F is viewed as a distribution of match specific productivities. Suppose further that every employer is an island and that there are no constraints on the number of jobs. However, each job dies at the exponential rate δ. The purpose of these assumptions is to abstract from the two externalities already identified by returning to the original specification but relaxing the assumption that the wage equals match specific productivity. To make the exposition even more similar, we suppose that employer's don't recruit. Later we discuss the consequences of relaxing that and other restrictions.

Let x denote a particular match specific realization drawn from F. Under the assumptions, the employer is willing to pay the worker involved a wage up to the value of x since there are no constraints on the number of employees that can be hired and the match specific productivity of each worker is independent of the total number of employees by assumption. Clearly, if x is less than the worker's reservaton wage, w^*, there is no bargain possible -- the worker continues to search. But if the difference, $x - w^*$, is positive there is a surplus to be haggled over. Suppose that the "going" solution to these bargaining problems in the market is that workers receive the positive constant share Θ of the surplus. In other words, the productivity contingent wage is determined by the bargaining outcome rule

$$(4.22) \qquad w(x) = w^* + \Theta(x-w^*), \quad 0 < \Theta < 1,$$

where w^* is to be interpreted as the common worker reservation wage, not necessarily that of an individual worker. The justification for this assumption is that every employer knowing that all workers are identical ex ante views an attempt by any individual to claim a higher reservation wage than that of his or her fellow appropriately as a false threat. Hence, the wage offer is determined as a weighted average of the match specific realized productivity and the common reservation wage.

Equation (4.22) and the distribution of match specific productivity F induce a distribution of wage offers that the worker can expect, which we call G. Formally,

$$(4.23) \qquad G(w) = \Pr\{w(x) < w\} = \Pr\{x < w^* + (w-w^*)/\Theta\} = F(w^* + (w-w^*)/\Theta)$$

where w^* is dropped as an explicit argument to make the point that no individual worker alone can affect the distribution. The reservation wage choice problem is identical to that formulated originally except that G replaces F as the wage offer distribution. Consequently, the worker reservation wage given the offer distribution is the solution to

$$(4.24) \qquad w^* = b-c + (\lambda/\delta) \int_{w^*}^{\infty} [w-w^*]dG(w)$$

provided that the participation condition ($w^* > b$) is satisfied. An equilibrium in this model is a wage offer distribution G and a reservation wage w^* that simultaneously satisfy (4.23) and (4.24).

By substituting from (4.22) and changing the variable of integration from w to x, which is equivalent to substituting from (4.23), one finds that the equilibrium common worker reservation wage is the solution to

$$(4.25) \qquad w^* = b-c + (\lambda\Theta/\delta) \int_{w^*}^{\infty} [x-w^*]dF(x).$$

Clearly, the equilibrium reservation wage is unique for every Θ and increases with it. But we have already shown in this model that the reservation wage that maximizes net output per worker, call it w^o, is the solution to (4.25) when the worker is paid marginal productivity, $\Theta = 1$. Since $w^o > w^*$ for all $\Theta < 1$, there is too little unemployment in equilibrium because workers do not take account of the employer's profit equal to the employer's share of the surplus associated with any match.

When the cost of search is the same whether employed or not and search effort can be chosen by the worker subject to increasing costs, a worker's search effort s^* increases with the worker's share of any surplus, Θ, and the equilibrium unemployment rate is

$$P(b,w^*) = \delta/[\delta-s^*\lambda(1-F(b))]. \tag{4.26}$$

Because the socially optimal amount of search effort, s^o, maximizes net output per worker, s^o exceeds s^*, the equilibrium unemployment rate is too high. The effect of the externality is to lengthen the expected duration of search in this case.

Of course, if the employer obtains a share of the match specific surplus, then there is an incentive to recruit. Allowing the employer to do so yields a two-sided search model such as those analyzed by Mortensen [1982a,1982b] and Pissarides [1984]. When both sides search, the external effect isolated here is present on both sides of the market. Just as the worker does not take account of the employer's share of the surplus in his search allocation decision, so the employer ignores the worker's share when allocating resources to recruiting. Unemployment is again too high in the simple stopping formuation and too low when both make allocations that affect the meeting rate.

F. Implicit Labor Contracts and Search: A Future Research Topic

Contributions to the theory of "reputational" competition among employers known as implicit contract theory has developed into a considerable and insightful literature in recent years. In spite of the intent of its founders, Azariadis [1975] and Baily [1974], most of the literature abstracts from the phenomena search theory is intended to explain, search unemployment and turnover. Conversely, most recent contributors to search theory have ignored the broader implications of implicit contract theory for the determination of wage policies and other job characteristics of interest to workers. It is the opinion of this author that the development of search models set in the context of an implicit contract theory of "personnel policy" determination and, conversely, the study of implicit contract formulations that use search theoretic explanations of the job finding and turnover processes are potentially very fruitful topics for future research. The purpose of this section is to briefly develop a case for this position and then to present an example that illustrates the point.

Implicit contract theory can be regarded as a formulation of the "long run" demand for labor by "reputable" employers in a changing environment characterized by an uncertain future. These are firms that expect to be in business indefinitely and consequently recognize the need to attract workers both now and in the future. Under these conditions, each has an incentive to establish and maintain "labor policies" that both current and prospective employees can depend on even in the face of changing future circumstances. These policies do not explicitly specify what the worker's wage or the probability of layoff will be at every future date. Instead, they embody the contingent rules that the employer will use to determine these variables when that future date arrives. Of course, the predominant application of this idea is the demonstration that equilibrium long run contracts can provide for the efficient sharing of risk between employers and workers, a function that is impossible for a Walrasian spot market for labor services. However, the more general point is that the exchange in the labor market is not simply a trade of labor services for a money wage at a point in time. Instead the labor market promotes the formation of viable employee-employer relationships that are expected to last for some period of time as a consequence of embodied specific capital of a variety of forms. One of those forms arises because of and others such as job-specific training are promoted by the fact that there are costs of forming and finding alternatives to the relationship for both parties. But, of course, the formation and turnover of such relationships is the subject matter of the related theories of search and matching.

For employers to have an incentive to develop reputations, the workers must necessarily know of them. An understanding of the potential synergy obtained by combining the two approaches requires that one recognize there is no need to suppose imperfect information about policies followed by particular employers in order to find a role for search behavior. Even if perfect information prevails concerning the terms of implicit contracts, a worker at a given date is not likely to know the realized contingencies that prevail at employing firms other than the worker's own or across firms when the worker is not employed. Hence, the role of search for the worker is to find the employer whose circumstances are relatively more favorable to the worker in the short run among those who offer policies or implicit contracts that the worker in question prefers over the long run. Given this structure, competition for workers among employers is a process of setting the terms of one's contract offer to appeal to either the largest number and/or a particular type of worker. Because these ideas are not well developed in the literature, an example follows that illustrates them and their implications for the issues of interest in this paper.

Feldstein's [1976] analysis of the effects of an experience rated UI tax on layoff unemployment is a well known example of an application of the implicit contract formulation. If UI benefits are taxed like other labor income and the tax used to finance the benefits is fully experience rated in the sense that an employer's tax payments are equal in expected value to the future UI benefits to be collected by the firm's employees, then the unemployment compensation system is neutral in the sense that layoff decisions are invariant to its parameters, say the benefit level. In a recent paper, Mortensen [1983], I obtained a similar result when the unemployed search and when employer's compete in terms of the implicit contracts they offer. The result differs from the standard search theoretic implication that an increase in the UI benefit level increase the expected duration of search whether the UI tax is fully experience rated or not.

A simple way to illustrate the argument is to suppose that each employer's "policy" specifies that any worker who arrives will be hired at some announced non-contingent wage, provided that the realized match specific productivity is above some announced critical value. The worker's decision is to search among those firms offering that policy which maximizes his or her own average lifetime income, a function of the announced wage when employed and the average duration of search implicit in the announced critical productivity value, and then go to work for the first one offering employment. Employers choose among policies which are parameterized by the critical value used to screen workers and the wage paid so as to maximize long run profit subject to the constraint that the policy chosen yields workers an expected average net income per period no less than that offered by the competition. Finally, expected profits are zero in equilibrium, at least under conditions of constant returns to scale. One can show that the only equilibrium policies are those characterized by a critial employer acceptance productivity exactly equal to what the workers would choose were they simply offered a wage equal to their realized productivity in any match. In other words, the two models have equivalent implications for the equilibrium unemployment rate, at least in the absence of unemployment compensation.

However, given an unemployment compensation scheme in which the employer pays a tax per worker equal to the expected future unemployment benefit per worker, the level of the reservation productivity is independent of the benefit level in the implicit contract formulation but not under the assumption that the wage equals realized productivity less the average UI tax per worker. No individual worker's net wage when employed depends on his own search behavior when unemployed in the latter formulation. Instead, it depends on the average duration of unemployment of all workers which is determined by reservation wage chosen by all the others. For that reason, equilibrium unemployment generally increases with the benefit level. However, the market for implicit contracts internalizes this externality by enforcing an equilibrium with the property that the employer acts as if the UI tax paid depends on the reservation productivity chosen. Specifically, equilibrium contracts that specify a higher reservation productivity must offer a wage that is lower by the amount of the higher tax required to pay the UI benefit received by workers who choose to search among the firms offering that contract when they are unemployed.

This argument is virtually identical to one used by Ramaswami [1983] to show that Hall's congestion externality is also internalized in an implicit contract framework. One obvious question for future research is whether other apparent external effects survive such an analysis.

FOOTNOTES

[1]See DeGroot [1970] and Chow et. al. [1971] for extensive treatment of optimal stopping as a statistical decision theory problem.

[2]See Felder [1975] for an empirical analysis of the method of search used by individual workers based on data from the Denver/Seattle Income Maintenance Experiment.

[3]Authors of original formulations of the wage search model implicitly assume that offers arrive at a average rate equal to one per unit time period. The empirical importance of the rate at which offers arrive as a determinant of unemployment durations was clearly demonstrated by Barron [1975]. Lippman and McCall [1976a] treat the case of random offer arrivals of no more than one per unit time period. The formulation of the offer arrival process adopted in this paper follows that of Wilde [1977].

[4]See DeGroot [1970] for an analysis of the optimal stopping problem in the case of an unknown distribution and Rothschild [1974] for an application of the optimal stopping approach to the problem of price search when the distribution is not known. Lippman and McCall [1976b] study the case of a known but time varying distribution of wage offers.

[5]For a discussion of differences that arise when recall is allowed, see Lippman and McCall [1976a].

[6]Notable exceptions to the general rule include Danforth [1979], Hall et. al. [1979], and Burdett and Mortensen [1978].

[7]Examples of the original literature on the topic are included in Katz [1977]. Also see Ehrenberg and Daxaca [1976] and Klassen [1979]. More recent related contributions include Topel [1983] and Clark and Summers [1982].

[8]Burdett [1978] analyzes the general case.

[9]Generalizations and applications of the job search model with an endogenously determined search intensity are contained in Mortensen [1977], Burdett and Mortensen [1978], and Burdett [1979].

[10]This assertion can easily be proved by contradition. The supposition that W(w) in non-increasing implies that the right side of (3.2) is strictly increasing in w.

[11]However, in the formalization presented in Jovanovic and here, the worker is assumed to be able to find new employment opportunities costlessly and instantaneously. This assumption is made for the purpose of focussing the analysis on the learning process. It can be relaxed without changing the essence of the results reported in this section.

[12]For an introduction, to the "two-armed bandit" problem, see DeGroot [1970]. Rothschild [1973] applies the model to a number of economic problems.

[13]One might imagine that the employer monitors the worker's realized productivity from time to time choosing the dates at random.

[14]Formal proofs of these assertions can be obtained from the author.

[15]Examples of this literature include Holt [1970], Hall [1972], Marston [1976], and Clark and Summers [1979, 1982].

[16]The specification outlined in this and the previous paragraph deviates from that of Lucas and Prescott [1974] in two repects. Frist, they allow diminishing returns to labor on each island, and, second, they assume search only while unemployed.

[17]An earlier demonstration of a similar result is reported in Axell [1977].

[18]The argument explains why the equilibrium unemployment rate is socially efficient in the original Lucas and Prescott [1974] model even though diminishing returns to labor on each island is assumed. Specifically, they assume that the flows of searching workers move to the islands where expected marginal productivity is highest.

REFERENCES

Axell, B. [1977]: "Search Market Equilibrium," Scandinavian Journal of Economics, 79, 20-40.

Azariadis, C., [1975]: "Implicit Contracts and Unemployment Equilibria," Journal of Political Economy 83, 1183-1202.

Bartel, A.P., and G.J. Borjas [1981]: "Wage Growth and Job Turnover: An Empirical Analysis," in S. Rosen, ed., Studies in Labor Markets, University of Chicago Press, Chicago.

Baily, M.N., [1974]: "Wages and Employment under Uncertain Demand," Review of Economic Studies, 41, 37-50.

Barron, J.M., [1975]: "Search in the Labor Market and the Durations of Unemployment," American Economic Review, 65, 934-942.

Bellman, R., [1957]: Dynamic Programming. Princeton University Press, Princeton, N.J.

Benhabib, J., and C. Bull [1983]: The Choice of Intensity," Journal of Political Economy 91, 747-764.

Blackwell, D., [1965]: "Discounted Dynamic Programming," Annals of Mathematical Statistics, 36, 226-235.

Burdett, K., [1981]: "A Useful Restriction on the Offer Distribution in Job Search Models," In G. Eliasson, B. Holmlund, and F.P. Stafford, eds., Studies in Labor Market Behavior: Sweden and the United States, I.U.I. Conference Report. Stockholm, Sweden.

Burdett, K., [1978]: "Employee Search and Quits," American Economic Review, 68, 212-220.

Burdett, K., [1978]: "Search, Leisure, and Individual Labor Supply" in Lippman and McCall [1979].

Burdett, K. and K.L. Judd [1983]: "Equilibrium Price Dispersion," Econometrica, 51, 955-970.

Burdett, K., N. Kiefer, D.T. Mortensen and G. Neumann [1982]: "Earnings, Unemployment and the Allocation of Time Over Time," forthcoming in G. Neumann and N. Westergaard-Nielsen, eds., in Labor Market Dynamics, Springer-Verlag, Heidelberg.

Burdett, K., and D.T. Mortensen [1978]: "Labor Supply under Uncertainty" in R.G. Ehrenberg ed., Research in Labor Economics, vol. 2, 109-158. JAI Press, Greenwich, Conn.

Burdett, K. and D.T. Mortensen [1980]: "Search, Layoffs, and Labor Market Equilibrium," Journal of Political Economy, 88, 652-72.

Butters, G.R., [1977]: "Equilibrium Distributions of Sales and Advertising Prices," Review of Economic Studies, 44, 465-491.

Chow, Y.S., H. Robbins, and D. Siegmund [1971]: Great Expectations: The Theory of Optimal Stopping, Houghton-Mifflin Co., Boston, Mass.

Clark, K.B., and L.H. Summers [1979]: "Labor Market Dynamics and Unemployment: A Reconsideration," Brooking Papers on Economic Activity 1, 13-72.

Clark, K.B., and L.H. Summers [1982]: "Unemployment Insurance and Labor Market Transitions," in Baily, M.N., ed., Workers, Jobs, and Inflation, The Brookings Institution, Washington, D.C.

Classen, K.P., [1979]: "Unemployment Insurance and Job Search," in Lippman and McCall [1979], 191-219.

Coleman, T.S. [1983]: "A Dynamic Model of Labor Supply under Uncertainty," presented at the North American Summer Meeting of the Econometric Society, Northwestern University, June, 1983.

Danforth, J.P., [1979]: "On the Role of Consumption and Decreasing Absolute Risk Aversion in the Theory of Job Search," in Lippman and McCall [1979], 109-131.

Diamond, P.A., [1971]: "A Model of Price Adjustment," Journal of Economic Theory, 3, 156-68.

Diamond, P.A., [1981]: "Mobility Costs, Frictional Unemployment, and Efficiency," Journal of Political Economy, 89, 789-812.

DeGroot, M.H., [1970]: Optimal Statistical Decisions, McGraw-Hill, Inc., New York, N.Y.

Ehrenberg, R.G., and R.L. Oaxaca [1976]. "Unemployment Insurance, Duration of Unemployment, and Subsequent Wage Gain, American Economic Review, 66, 754-766.

Felder, H.E., [1975]: "Job Search: An Empirical Analysis of Search Behavior of Low Income Workers," Research Memorandum #25, Stanford Research Institute.

Feldstein, M.S., [1976]: "Temporary Layoffs in the Theory of Unemployment," Journal of Political Economy, 84, 937-57.

Feller, W., [1957]: An Introduction to Probability Theory and Its Applications, vol. 1, 2nd ed., John Wiley & Sons, Inc., New York.

Flinn, C.J., [1983]: "Wages and Job Mobility of Young Workers," IRP Discussion Paper #728-83, University of Wisconsin-Madison.

Flinn, C., and J.J. Heckman [1983]: "Are Unemployment and Out of the Labor Force Behaviorally Distinct Labor Force States?," Journal of Labor Economics, 1, 28-42.

Flinn, C., and J.J. Heckman [1982a]: "Models for the Analysis of Labor Force Dynamics," in R. Basmann and G. Rhodes, eds., Advances in Econometrics, JAI Press, Greenwich, Conn.

Flinn, C., and J.J. Heckman, [1982b]. "New Methods for Analyzing Structural Models of Labor Force Dynamics," Journal of Econometrics, 18, 115-168.

Goldberger, A.S., [1980]: "Abnormal Selection Bias," 8006 SSRI Workshop Series, University of Wisconsin, Madison, Wisconsin.

Gronau, R., [1971]: "Information and Frictional Unemployment," American Economic Review, 61, 290-301.

Gronau, R., [1974]: "Wage Comparison — A Selectivity Bias," Journal of Political Economy, 82, 1119-1144.

Hall, J.R., S.A. Lippman, and J.J. McCall [1979]: "Expected Utility Maximizing Job Search" in Lippman and McCall [1979], 133-155.

Hall, R.E., [1972]: "Turnover in the Labor Force," Brookings Papers on Economic Activity, 709-56.

Hall, R.E., [1979]: "A Theory of the Natural Unemployment Rate and the Duration of Employment," Journal of Monetary Economics, 5, 153-169.

Heckman, J.J., and G. Borjas [1980]: "Does Unemployment Cause Future Unemployment? Definitions, Questions and Answers from a Continuous Time Model of Heterogeneity and State Dependence," Economica, 47, 247-283.

Heckman, J.J., and B. Singer [1982]: "The Identification Problem in Econometric Models for Duration Data," in W. Hildenbrand, ed., Advances in Econometrics, Cambridge, U.K., Cambridge University Press, 39-77.

Hirshleifer, J., [1973]: "Where Are We in the Theory of Information?," American Economic Review, 87, 31-39.

Holt, C. [1970]: "Job Search, Phillips Wage Relation, and Union Influence: Theory and Evidence in Phelps et. al. [1970].

Johnson, W., [1978]: "A Theory of Job Shopping," Quarterly Journal of Economics, 92, 261-277.

Jovanovic, B., [1979a]: "Job-Matching and the Theory of Turnover," Journal of Political Economy, 87, 972-90.

Jovanovic, B., [1979b]: "Firm-specific Capital and Turnover," Journal of Political Economy, 87, 1246-1260.

Jovanovic, B., [1984]; "Matching, Turnover and Unemployment," Journal of Political Economy 92, 108-122.

Jovanovic, B., [1983]: "Turnover, Unemployment and the Cycle," mimeo, New York University.

Kasper, H., [1967]: "The Asking Price of Labor and the Duration of Unemployment," Review of Economics and Statistics, 49, 165-172.

Kalbfleish, J., and R. Prentice [1980]: The Statistical Analysis of Failure Time Data, Wiley, New York.

Katz, A., ed. [1977]: "The Economics of Unemployment Insurance: A Symposium," Industrial & Labor Relations Review, 30, July.

Kiefer, N., and G. Neumann [1979a]: "An Empirical Job Search Model with a Test of the Constant Reservation Wage Hypothesis," Journal of Political Economy, 87, 69-82.

Kiefer, N., and G. Neumann [1979b]: "Estimation of Wage Offer Distributions and Reservation Wages" in Lippman and McCall [1979].

Kiefer, N., and G. Neumann [1981]: "Individual Effects in a Nonlinear Model: Explicit Treatment of Heterogeneity in the Empirical Job Search Model," Econometrica, 49, 1981.

Kohn, M.G., and S. Shavell [1974]: "The Theory of Search," Journal of Economic Theory, 9, 93-123.

Lippman, S.A., and J.J. McCall [1976b]: "The Economics of Job Search, A Survey," Economic Inquiry, 14, 155-189 and 347-368.

Lippman, S.A., and J.J. McCall, [1976b]: "Job Search in a Dynamic Economy," Journal of Economic Theory, 12, 365-390.

Lippman, S.A., and J.J. McCall, eds., [1979]: Studies in the Economics of Search, North-Holland Publishing Company, New York, N.Y.

Lancaster, T., and S. Nickell [1980]: "The Analysis of Reemployment Probabilities for the Unemployed," Journal of the Royal Statistical Society (Series A), 135, 257-271.

Lucas, R. Jr., and E.C. Prescott [1974]: "Equilibrium Search and Unemployment," Journal of Economic Theory, 7, 188-209.

Lundberg, S., [1981]. Unemployment and Household Labor Supply, Ph.D. Dissertation, Northwestern University, Evanston, IL.

Marshall, R.C., [1983]: "The Effect of Job Specific Human Capital Accumulation on Wages: A Censored Regression Approach", unpublished paper, University of Virginia.

Marston, S.T. [1976]: "Employment Instability and High Unemployment Rates," Brookings Papers on Economic Activity 1, 169-210.

Mattila, J.P. [1974]: "Job Quitting and Frictional Unemployment," American Economic Review 64, 235-240.

McCall, J.J., [1970]: "Economics of Information and Job Search," Quarterly Journal of Economics, 84, 113-126.

Mincer, J., [1974]: Schooling, Experience, and Earnings, Columbia University Press, New York.

Mincer, J., and B. Jovanovic [1981]: "Labor Mobility and Wages" in S. Rosen, ed., Studies in Labor Markets, NBER Conference Report, University of Chicago Press, Chicago.

Mortensen, D.T. [1970]: "A Theory of Wage and Employment Dynamics," in Phelps et. al. [1970].

Mortensen, D.T. [1983]: "A Welfare Analysis of Unemployment Insurance: Variations on Second Best Themes," Carnegie-Rochester Series on Public Policy, 19, 67-98.

Mortensen, D.T. [1976]: "Job Matching and Under Imperfect Information," in O. Ashenfelter and J. Blum, eds., Evaluating the Labor Market Effects of Social Programs, Princeton University Press, Princeton, N.J.

Mortensen, D.T., [1970]: "Job Search, the Duration of Unemployment, and the Phillips Curve," American Economic Review, 60, 505-517.

Mortensen, D.T., [1982a]: "Property Rights and Efficiency in Mating, Racing and Related Games," American Economic Review, 72, 968-979.

Mortensen, D.T., [1978]: "Specific Capital and Labor Turnover," Bell Journal of Economics, 9, 572-586.

Mortensen, D.T., [1977]: "Unemployment Insurance and the Labor Supply Decision" in Katz [1977].

Mortensen, D.T., [1982b]: "The Matching Process as a Noncooperative Bargaining Game," in J.J. McCall, ed., The Economics of Information and Uncertainty, NBER, University of Chicago Press, Chicago.

Mortensen, D.T., and G. Neumann [1983]: "Choice or Chance? A Structural Interpretation of Individual Labor Market Histories" forthcoming in G. Neuman and N. Westergaard-Nielsen, Labor Market Dynamics, Springer-Verlag, Heidelberg.

Nickell, S., [1979]: "Estimating the Probability of Leaving Unemployment", Econometrica, 91, 39-57.

Parsons, D.O., [1977]: "Models of Labor Turnover, A Theoretical and Empirical Survey," in R. Ehrenberg, ed., Research in Labor Economics, vol. 1, 185-225 JAI Press, Greenwich, Conn.

Phelps, E.S., et. al. [1970]: Microeconomic Economic Foundations of Employment and Inflation Theory, W.W. Norton, New York, N.Y.

Pissarides, C.A. [1984]: "Search Intensity, Advertising, and Efficiency", Journal of Labor Economics, 2, 128-143.

Prescott, E.C., [1975]: "Efficiency of the Natural Rate," Journal of Political Economy, 83, 1229-1236.

Ramaswami, C., [1983]: "Equilibrium Unemployment and the Efficient Job-finding Rate," Journal of Labor Economics, 1, 177-196.

Rothschild, M., [1973]: "Models of Market Organization with Imperfect Information: A Survey," Journal of Political Economy, 81, 1283-1308.

Rothschild, M. [1974]: "Searching for the Lowest Price When the Distribution of Prices is Unknown," Journal of Political Economy, 82, 689-711.

Rothschild, M., [1973]: "A Two-Armed Bandit Theory of Pricing," Journal of Economic Theory, 9, 185-202.

Rothschild, M., and J. Stiglitz, [1970], "Increasing Risk I: A Definition," Journal of Economic Theory, 2, 225-243.

Salant, S., [1977]: "Search Theory and Duration Data: A Theory of Sorts," Quarterly Journal of Economics, 39-58.

Salop, S.C., [1979]: "A Model of the Natural Rate of Unemployment," American Economic Review, 69, 117-25.

Salop, S.C., [1973]: "Systematic Job Search and Unemployment," Review of Economic Studies, 40, 191-201.

Seater, J.J., [1977]: "A Unified Model of Consumption, Labor Supply and Job Search," Journal of Economic Theory 14, 349-372.

Stigler, G.J., [1961]: "The Economics of Information," Journal of Political Economy, 69, 213-225.

Stigler, G.J., [1962]: "Information in the Labor Market," Journal of Political Economy, 70, 94-104.

Toikka, R., [1976]; "A Markovian Model of Labor Market Decisions by Workers," American Economic Review, 66, 821-834.

Tobin, J., [1972]: "Inflation and Unemployment," American Economic Review, 62, 1-18.

Topel, R., [1983]: "On Layoffs and Unemployment Insurance," American Economic Review, 73, 541-559.

Weiner, S.E., [1982]: "A Survival Analysis of the Adult Male Black/White Unemployment Rate Differential," forthcoming in G. Neumann and N. Westergaard-Nielsen, eds., Labor Market Dynamics, Springer-Verlag, Heidelberg.

Welch, F., [1977]: "What Have We Learned from Empirical Studies of Unemployment Insurance?" in Katz [1977].

Wilde, L.L., [1979]: "An Information-theoretic Approach to Job Quits," in Lippman and McCall [1979].

Wilde, L.L., [1977]: "Labor Market Equilibrium under Nonsequential Search," Journal of Economic Theory, 16, 373-393.

Viscusi, W.K., [1979]: "Job Hazards and Worker Quit Rates: An Analysis of Adaptive Worker Behavior," International Economic Review, 20-58.