The Economics of Search*

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Abstract

The economics of search study the implications of frictions for individual behavior and market performance, due usually to imperfect information about exchange possibilities. This article reviews labor-market research in this area. Individuals search for a job offer by choosing a reservation wage and accepting jobs that pay above that wage. Firms create jobs to maximize profit. The probability of realizing a match is derived from an aggregate matching function that gives the number of jobs formed in terms of the search efforts of firms and workers. Because of monopoly rents implied by frictions, wages are determined either by bargaining or by take-it-or-leave it offers posted by firms. Bargaining models share the surplus and give rise to a single wage for homogeneous labor that in general does not allocate jobs efficiently. Wage posting can give rise to a single wage equal to the worker's reservation wage if the worker can only observe one wage offer at a time, or to the efficient allocation if posted wages can be observed but there are job queues, or to a distribution of wage offers if employed workers can sample more than one firm at a time. Job destruction is due either to job-specific shocks or to technological obsolescence.

The economics of search study the implications of market frictions for economic behavior and market performance. "Frictions" in this context include anything that interferes with the smooth and instantaneous exchange of goods and services. The most commonly-studied problems arise from imperfect information about the location of buyers and sellers, their prices and the quality of the goods and services that they trade. The key implication of these frictions is that individuals are prepared to spend time and other resources on exchange; they *search* before buying or selling. The labor market has attracted most theoretical and empirical interest in this area of research,

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because of the heterogeneities that characterize it and the existence of good data on flows of workers and jobs between activity and inactivity, which can be used to test its propositions.

1 Historical background

The first formal model of individual behavior, due to Stigler (1961), was in the context of a goods market: choosing the optimal number of sellers to search before buying at the lowest price. Stigler's rule, known as a fixed-sample rule, was abandoned in favor of sequential stopping rules: choosing the optimal reservation price and buying at the first store encountered which sells at or below the reservation price (see McCall 1970 for an early influential paper).

The first big momentum to research in the economics of search came with the publication of Phelps et al. (1970), which showed that search theory could be used to analyze the natural rate of unemployment and the inflation-unemployment trade off, the central research questions of macroeconomics at that time. Although interest in the inflation-unemployment trade-off has since waned, interest in search theory as a tool to analyze transitions in the labor market and equilibrium unemployment has increased. The momentum in this direction came in the 1980s, when contributions by Diamond (1982), Mortensen (1982) and Pissarides (1985) showed that search theory could be used to construct equilibrium models of the labor market with more accurate predictions than the traditional neoclassical model (see Pissarides 2000 and Mortensen and Pissarides 1999a,b for reviews). The appearance of comprehensive data on job and worker flows, which can be studied with the tools of search theory, also contributed to interest in this direction (see Leonard 1987, Dunne et al. 1989, Davis et al. 1996, Blanchard and Diamond 1990). This article reviews major developments since the mid 1980s, with explicit reference to labor markets.

2 Job search

An individual has one unit of labor to sell to firms, which create jobs. The valuation of labor takes place under the assumptions that agents have infinite horizons and discount future income flows at the constant rate r, they know the future path of prices and wages and the stochastic processes that govern the arrival of trading partners, and they maximize the present discounted value of expected incomes. Let U_t be the expected present discounted value of a unit of labor before trade at time t (the "value" of an unemployed worker) and W_t the expected value of an employed worker. During a short time interval δt the unemployed worker receives income $b\delta t$, and a job offer arrives with probability $a\delta t$. The frictions studied in the economics of search are summarized in the arrival process. In the absence of frictions, $a \to \infty$. With frictions and search, $a > 0$; with no search, $a = 0$. A large part of the literature is devoted to specifying the arrival process, an issue addressed in Sect. 3.1. The choice of search intensity has also been studied, by making a an increasing function of search effort, but this issue is not addressed here (see Pissarides 2000 chap. 5).

If a job offer arrives, the individual has the option of taking it, for an expected return $W_{t+\delta t}$; or not taking it and keeping instead return $U_{t+\delta t}$. If no offer arrives, the individual's return is $U_{t+\delta t}$. Therefore, with discount rate r, U_t satisfies the Bellman equation

$$U_t = b\delta t + a\delta t \frac{\max(W_{t+\delta t}, U_{t+\delta t})}{1 + r\delta t} + (1 - a\delta t)\frac{U_{t+\delta t}}{1 + r\delta t}. \tag{1}$$

Rearrangement of terms yields

$$rU_t = b + a\left(\max(W_{t+\delta t}, U_{t+\delta t}) - U_{t+\delta t}\right) + \frac{U_{t+\delta t} - U_t}{\delta t}. \tag{2}$$

Taking the limit of (2) as $\delta t \to \infty$, and omitting subscripts for convenience, yields

$$rU = b + a\left(\max(W, U) - U\right) + \dot{U}, \tag{3}$$

where $\dot{U}$ denotes the rate of change of U.

Equation (3) is a fundamental equation in the economics of search. It can be given the interpretation of an arbitrage equation for the valuation of an asset in a perfect capital market with risk-free interest rate r. This asset yields coupon payment b and at some rate a, it gives its holder the option of a discrete change in its valuation, from U to W. Optimality requires that the option is taken (and the existing valuation given up) if $W \geq U$. The last term, $\dot{U}$, shows capital gains or losses due to changes in the market valuation of the asset. In most of the economics of labor-market search, however, research concentrates on "steady states", namely, on situations where the discount rate, transition rates and income flows are all constant. With infinite horizons there are then stationary solutions to the valuation equations, obtained from (3) with $\dot{U} = 0$.

One simple way of solving (3) is to assume that employment is an "absorbing state", so when a job that offers wage w is accepted, it is kept for life. Then, $W = w/r$, and if the individual is sampling from a known wage offer distribution $F(w)$, the stationary version of (3) satisfies

$$rU = b + a\left(\int \max(w/r, U)\,dF(w) - U\right). \tag{4}$$

The option to accept a job offer is taken if $w/r \geq U$, giving the reservation wage equation

$$\xi = rU. \tag{5}$$

The reservation wage is defined as the minimum acceptable wage, and it is obtained as the solution to (4) and (5).

Partial models of search and empirical research in the duration of unemployment have explored generalized forms of Eqn. (4) to derive the properties of transitions of individuals from unemployment to employment (see Devine and Kiefer, 1991). For a known $F(w)$ with upper support A, Eqn. (4) specializes to

$$\xi = b + \frac{a}{r}\int_{\xi}^{A} (w - \xi)\, dF(w). \tag{6}$$

Various forms of (6) have been estimated by the empirical literature or used in the construction of partial models of the labor market. The transition from unemployment to employment (the unemployment "hazard rate") is $a(1 - F(\xi))$ and it depends both on the arrival of offers and on the individual's reservation wage. a, r and the parameters of the wage offer distribution can be made to depend on the individual's characteristics. The empirical literature has generally found that unemployment compensation acts as a disincentive on individual transitions through the influence of b on the reservation wage, but the effect is not strong. The offer arrival rate increases the hazard rate, despite the fact that the reservation wage increases in a. A number of personal characteristics influence reservation wages and transitions, including age, education and race.

3 Two-sided matching for given wages

Recent work in the economics of search has focused mainly on the equilibrium implications of frictions and search decisions. An equilibrium model needs to specify the decisions of firms and solve for the offer arrival rate a. In addition, a mechanism is needed to ensure that search is an ongoing process. The latter is achieved by introducing a probability $\lambda\delta t$ that a negative shock will hit a job during a short time interval δt. When the negative shock arrives the job is closed down ("destroyed"), and the worker has to search again to find another job. For the moment, λ is assumed to be a positive constant (see Sect. 5).

3.1 The aggregate matching function

To derive the equilibrium offer arrival rate, suppose that at time t there are u unemployed workers and v vacant jobs. In a short time interval δt each unemployed worker moves to employment with probability $a\delta t$, so in a large market the total flow of workers from unemployment to employment, and the total flow of jobs from vacant state to production, are both $au\delta t$. A key assumption in the equilibrium literature is that the total flows satisfy an aggregate matching function. The aggregate matching function is a black box that gives the outcome of the search process in terms of the inputs into search. If the u unemployed workers are the only job seekers and they search with fixed intensity of one unit each, and firms also search with fixed intensity of one unit for each job vacancy, the matching function gives

$$m = m(u, v), \tag{7}$$

with m standing for the flow of matches, au. The function is usually assumed to be continuous and differentiable, with positive first partial derivatives and negative second derivatives, and to satisfy constant returns to scale (see Petrongolo and Pissarides, 2000, for a review). A commonly-used matching function in the theoretical literature, derived from the assumption of uncoordinated random search, is the exponential

$$m = v(1 - e^{-ku/v}), \qquad k > 0. \tag{8}$$

The empirical literature, however, estimates a log-linear (constant elasticity) form, which parallels the Cobb-Douglas production function specification, with the elasticity on unemployment estimated in the range 0.5-0.7.

The fact that job matching is pairwise implies that the transition rates of jobs and workers are related Poisson processes. Given $au = m$, the rate at which workers find jobs is $a = m/u$. If q is the rate of arrival of workers to vacant jobs, then total job flows $vq = au$, and so $q = m/v$. The equilibrium literature generally ignores individual differences and treats the average rates m/u and m/v as the rates at which jobs and workers, respectively, arrive to each searching worker and vacant job. By the properties of the matching function,

$$\begin{aligned} q &= m(\frac{u}{v}, 1) && (9) \\ &\equiv m(\theta^{-1}, 1) \equiv q(\theta) && (10) \end{aligned}$$

with $q'(\theta) < 0$ and elasticity $-\eta(\theta) \in (-1, 0)$. Here, θ is a measure of the tightness of the market, of the ratio of the inputs of firms into search to the inputs of workers. Similarly, the transition rate of workers is

$$a = m(1, \frac{v}{u}) \equiv \theta q(\theta). \tag{11}$$

By the elasticity properties of $q(\theta)$, $\partial a/\partial\theta > 0$. In the steady state, the inverse of the transition rates, $1/q(\theta)$ and $1/\theta q(\theta)$, are the expected durations of a vacancy and unemployment respectively.

The influence of tightness on the transition rates is independent of the level of wage rates. If there are more vacant jobs for each unemployed worker, the arrival rate of workers to the typical vacancy is lower and the arrival rate of job offers to the typical unemployed worker is higher, irrespective of the level of wages. When a worker and a firm meet and are considering whether or not to stay together, they are not likely to take into account the implications of their action for market tightness and the transition rates of other unmatched agents. For this reason, the influence of tightness on the transition rates is known as a **search externality.** Several papers in the economics of search have explored the efficiency properties of equilibrium given the existence of the externality (see Sect. 4.3.2 and Diamond 1982, Mortensen 1982, Pissarides 1984, Hosios 1990).

3.2 Job creation

A job is an asset owned by the firm and is valued in a perfect capital market characterized by the same risk-free interest rate r. Suppose that in order to recruit a worker, a firm has to bear set-up cost K to open a job vacancy and in addition has to pay a given flow cost c for the duration of the vacancy. The flow cost can be interpreted as an advertising and recruitment cost, or as the cost of having an unfilled position in what might be a complex business environment (which is not modeled).

Let V be the value of a vacant position and J the value of a filled one. Reasoning as in the case of the value of a job seeker, U, the Bellman equation satisfied by V is

$$rV = -c + q(\theta)(J - V). \tag{12}$$

The vacant job costs c and the firm is offered the option to take a worker at rate $q(\theta)$.

Since the firm has to pay set-up cost K to create a job, it will have an incentive to open a job if (and only if) $V \geq K$. The key assumption made about job creation is that the gains from job creation are always exhausted, so jobs are created up to the point where

$$V = K. \tag{13}$$

Substitution of V from (12) into (13) yields

$$J = K + \frac{rK + c}{q(\theta)}. \tag{14}$$

Competition requires that the expected present discounted value of profit when the worker arrives, the value of a filled job J, should be just sufficient to cover the initial cost K and the accumulated costs for the duration of the vacancy, interest on the initial outlay rK and ongoing costs c for the expected duration of the vacancy, $1/q(\theta)$.

Let productivity be a constant p in all jobs and the wage rate a constant w. With break-up rate λ, the value of a job satisfies the Bellman equation

$$rJ = p - w - \lambda J. \tag{15}$$

The flow of profit to the firm is $p - w$ until a negative shock arrives that reduces its value to 0. Replacing J in (14) by its expression in (15) yields the job creation condition

$$\frac{p-w}{r+\lambda} - K - \frac{rK+c}{q(\theta)} = 0. \tag{16}$$

Equation (16) determines θ for each w and parallels the conventional labor demand curve. A higher wage rate makes it more expensive for firms to open jobs, leading to lower market tightness. Frictions slow down the arrival of suitable workers to vacant jobs and so the firm incurs some additional recruitment costs. If the arrival rate is infinitely fast, as in Walrasian economics, $q(\theta)$ is infinite and the last term in (16) disappears. The assumptions underlying (13) ensure that at the margin, the recruitment cost is just covered.

4 Wage setting

With search frictions, there is no supply of labor that can be equated with demand to give wages. The conventional supply of labor is constant here: there is a fixed number of workers in the market, which is usually normalized to unity, and each supplies a single unit of labor.

In search equilibrium there are local monopoly rents. Firms and workers who are together can start producing immediately. If they break up, they can start producing only after they find another partner through an expensive process of search. The value of the search costs that they save by staying together correspond to a pure economic rent; they could be taken away from them and they would still stay together. Wages need to share those rents.

Two approaches dominate in the literature. The first and more commonly-used approach employs the solution to a Nash bargaining problem (see Diamond 1982, Pissarides 2000). The Nash solution allocates the rents according to each side's "threat points." The threat points in this case are the returns from search, and the Nash solution gives to each side the same surplus over and above their expected returns from search. Generalizing this solution concept, wages are determined such that the net gain accruing to the worker from the match, $W - U$, is a fixed proportion β of the total surplus, the sum of the worker's and the firm's surplus, $J - V$. This sharing rule can be obtained as the maximization of the product

$$(W-U)^{\beta}(J-V)^{1-\beta}, \qquad \beta \in (0,1). \tag{17}$$

The coefficient β can be given the interpretation of bargaining strength, although strictly speaking, bargaining strength in the conventional Nash solution is given by the threat points U and V (see Binmore et al. 1986 for an interpretation of β in terms of rates of time preference).

The second approach to wage determination postulates that the firm "posts" a wage rate for the job, which the worker either takes or leaves. The posted wage may be above the worker's reservation wage because of some "efficiency wage" type arguments, for example, in order to reduce labor turnover, encourage more effort or attract more job applicants.

4.1 Bargaining

The value of an employed worker, W, satisfies the Bellman equation

$$rW = w - \lambda(W - U). \tag{18}$$

The worker earns wage w and gives up the employment gain $W - U$ when the negative shock arrives. No worker has an incentive to quit into unemployment or search for another job whilst employed, for as long as $w \geq b$, which is assumed.

With (18) and (15) in place, the Nash bargaining solution to (17) gives the sharing rule

$$W - U = \beta(W - U + J - V). \tag{19}$$

Making use of the value equations and sharing rule yields

$$\begin{aligned} w &= rU + \beta(p - (r + \lambda)K - rU) & (20) \\ &= (1 - \beta)b + \beta[p - (r + \lambda)K + (rK + c)\theta]. & (21) \end{aligned}$$

There is a premium on the reservation wage which depends on the worker's bargaining strength and the net surplus produced. Wages depend positively on unemployment income and the productivity of the job, the first because of the effect that unemployment income has on the cost of unemployment and the second because of the monopoly rents and bargaining. Wages also depend on market tightness. In more tight markets they are higher, because the expected duration of unemployment in the event of disagreement is less. Empirical evidence supporting this wage equation has been found by a number of authors (e.g. Blanchflower and Oswald, 1994), although it should be noted that similar wage equations can also be derived from other theoretical frameworks.

4.2 Equilibrium

Equation (21) replaces the conventional labor supply curve and closes the system. When combined with the job creation condition (16) it gives unique solutions for wages and market tightness. A variety of intuitive properties are satisfied by this equilibrium. For example, higher labor productivity implies higher wages and tightness; higher unemployment income implies higher wages but lower tightness. It remains to obtain the employment rate in equilibrium.

The labor force size is fixed, so by appropriate normalizations, if at some time t unemployment is u_t, employment is $1 - u_t$. In a short time interval δt, $a_t u_t \delta t$ workers are matched and $\lambda(1 - u_t)\delta t$ workers lose their jobs. Given that $a_t = \theta_t q(\theta_t)$, the evolution of unemployment is given by

$$u_{t+\delta t} = u_t + \lambda(1 - u_t)\delta t - \theta_t q(\theta_t) u_t \delta t. \tag{22}$$

Dividing through by δt and taking the limit as $\delta t \to 0$ yields

$$\dot{u} = \lambda(1 - u) - \theta q(\theta) u. \tag{23}$$

Because the solution for θ is independent of u, this is a stable differential equation for unemployment with a unique equilibrium

$$u = \frac{\lambda}{\lambda + \theta q(\theta)}. \tag{24}$$

Equation (24) is often referred to as the Beveridge curve, after William Beveridge who first described such a "frictional" equilibrium. Plotted in space with vacancies on the vertical axis and unemployment on the horizontal is a convex-to-the origin curve. In the early literature the impact of frictions on the labor market was measured by the distance of this curve from the origin (see also Pissarides, 2000, Blanchard and Diamond, 1989).

4.3 Wage posting

Wage posting is an alternative to wage bargaining, with different implications for search equilibrium. The firm posts a wage for the job and the worker who searches it either takes it or leaves it. Three different models of wage posting are examined.

4.3.1 Single offers, no prior information

Workers search sequentially one firm at a time, they discover the firm's offer after they have made contact and they have to accept it or reject it (with no recall) before they can sample another firm. The worker who contacts a firm that posts wage w_i has two options. Accept the wage offer of the firm and enjoy expected return W_i, obtained from (18) for $w = w_i$, or reject it and continue search for return U. The firm that maximizes profit chooses w_i subject to $W_i \geq U$. Since the firm will have no incentive to offer the worker anything over and above the minimum required to make workers accept its offer, in this model wages are driven to the worker's reservation wage, $w_i = b$ (Diamond, 1971).

In terms of the bargaining solution, the "Diamond" equilibrium requires $\beta = 0$ (see (20), (21)). The model can then be solved as before, by replacing β by 0 in the job creation condition and wage equation. Tightness, and consequently unemployment, absorb all shocks other than those operating through unemployment income, which also change wages. (There is a paradox in this model, in that if wages are equal to unemployment income no worker will have an incentive to search.)

4.3.2 Competitive search

The next model increases the amount of information that workers have before they contact the firm (Moen, 1997). Workers can see the wage posted by each firm but because of frictions they cannot be certain that they will get the job if they apply. If the probability of a job offer across firms is the same, all workers will apply for the highest-wage job. Queues will build up and this will reduce the probability of an offer. In equilibrium, the wage offer and queue characterizing each job have to balance each other out, so that all firms get applicants.

The length of the queue is derived from the matching process. The firm that posts wage w_i makes an offer on average after $1/q(\theta_i)$ periods and a job applicant gets an offer on average after $1/\theta_i q(\theta_i)$ periods. Implicit in this formulation is the assumption that more than one firm offers the same wage, and firms compete for the applicants at this wage. Workers apply to only one job at a time.

Suppose now there is a firm, or group of firms, such that when workers join their queue they derive expected income stream $\bar{U}$, the highest in the market. The constraint facing a firm when choosing its wage offer is that the worker who applies to it derives at least as much expected utility as $\bar{U}$. The expected profit of the firm that posts wage w_i solves

$$rV_i = -c + q(\theta_i)(J_i - V_i) \tag{25}$$

$$rJ_i = p - w_i - \lambda J_i. \tag{26}$$

The worker's expected returns from applying to the firm posting this wage satisfy the system of equations

$$rU_i = b + \theta_i q(\theta_i)(W_i - U_i) \tag{27}$$

$$rW_i = w_i - \lambda(W_i - \bar{U}). \tag{28}$$

The firm chooses w_i to maximize V_i subject to $U_i \geq \bar{U}$. The first-order maximization conditions imply that all firms offer the same wage, which satisfies

$$W - U = \frac{\eta}{1-\eta}(J - V). \tag{29}$$

Comparison of (29) with (19) shows that the solution is indeed similar to the Nash solution but with the share of labor given by the (negative of the) elasticity of $q(\theta)$, (which is equal to the unemployment elasticity of the underlying matching function). The rest of the model can be solved as in the Nash case.

There is a special significance to the share of labor obtained in this formulation. In the case where wages are determined according to the Nash rules, the firm and worker choose the wage after they meet, so it is unlikely that they will internalize the search externalities; they do not take into account the effect of their choices on the transition rates of unmatched agents. It can be shown that with constant returns to scale there is a unique internalizing rule, which requires $\beta = \eta$, the solution of the wage posting model considered here (Hosios 1990, Pissarides 1984, 2000). For this reason, this particular wage posting model is often called the **competitive search** equilibrium. The key assumption that gives efficiency is the relaxation of the informational restrictions on workers, which lets them know both the firm's wage offer and the length of the queue associated with it.

4.3.3 Wage differentials

The third version of the wage posting model relaxes the assumption that workers have the choice of at most one wage offer at a time but does not allow workers knowledge of the wage offer before they apply (Burdett and Judd, 1983, Burdett and Mortensen, 1998, Montgomery, 1991). The easiest way to introduce this is to allow workers the possibility of search on the job, i.e. to let them continue looking for a better job after they accepted one. Suppose for simplicity that job offers arrive to searching workers at the same rate a, irrespective of whether they are employed or unemployed. Suppose also that job search is costless (except for the time cost) and job changing is costless. Then, if a worker is earning w now and another offer paying w' comes along, the worker accepts the new offer if (and only if) $w' > w$. The worker's reservation wage is the current wage.

Unemployment pays b, so no firm can pay below b and attract workers. Consider a firm that pays just above b. Anyone applying for a job from the state of unemployment will accept its offer, but no one else will. Employed job seekers will have no incentive to quit their jobs to work at a wage close to b. In addition, this firm's workers will be quitting to join other firms, which may be paying above b. So a firm paying a low wage will have high turnover and will be waiting long before it can fill its vacancies.

A firm paying a high wage will be attracting workers both from unemployment and from other firms paying less than itself. Moreover, it will not be losing workers to other firms. So high-wage firms will have fewer vacant positions.

Now suppose the two firms have access to the same technology. The low-wage firm enjoys a lot of profit from each position, but has a lot of vacant positions. The high-wage firm enjoys less profit from each position, but has them filled. It is possible to show under general conditions that high wage and low wage firms will co-exist in equilibrium.

Burdett and Mortensen (1998) show this by assuming that there is a distribution of wage offers for homogeneous labor, $F(w)$, and demonstrating that (a) no two firms will offer the same wage, (b) firms can choose any wage between the minimum b and a maximum $\bar{w}$, and enjoy the same profit in the steady state. The maximum is given by

$$\bar{w} = p - \left(\frac{\lambda}{a + \lambda} \right)^2 (p - b), \tag{30}$$

where as before p is the productivity of each worker and λ the job destruction rate.

The interesting result about wage posting in this model is that once the assumption that the worker can only consider one offer at a time is relaxed, a distribution of wage offers for homogenous labor arises. The distribution satisfies some appealing properties. As $a \to 0$, the upper support tends to $\bar{w} = b$, the Diamond solution. At the other extreme, as $a \to \infty$, it can be shown that all wage offers converge to p, the competitive solution. Intuitively, $a = 0$ maximizes the frictions suffered by workers and $a = \infty$ eliminates them.

5 Job destruction

A body of empirical literature shows that there is a lot of "job churning," with many jobs closing down and new ones opening to take their place. It is also found that both the job creation and job destruction rates, especially the latter, vary a lot over the cycle (see Leonard 1987, Dunne et al. 1989 and Davis et al. 1996). This is an issue addressed by search theorists. Returning to the model with a Nash wage rule, the job creation flow is the matching rate $m(u, v)$. The job creation rate is defined as the job creation flow divided by employment, $m(u, v)/(1 - u)$, which is

$$\frac{m(u, v)}{1 - u} = \theta q(\theta) \frac{u}{1 - u}. \tag{31}$$

Since both θ and u are endogenous variables of the model that respond to shocks, the model predicts a variable job creation rate that can be tested against the data (see Mortensen and Pissarides 1994, Cole and Rogerson 1999).

But the job destruction flow is $\lambda(1 - u)$, so the job destruction rate is a constant λ, contrary to observation. Two alternative ways of making it variable are considered.

5.1 Idiosyncratic shocks

In the discussion so far, the productivity of a job is p until a negative shock arrives that reduces it to zero. Generalizing this idea, suppose that although initially the productivity is p, when a shock arrives it changes it to some other value px. The component p is common to all jobs but x is specific to each job. It has distribution $G(x)$ in the range $[0, 1]$. New jobs start with specific productivity $x = 1$; over time shocks arrive at rate λ that transform this productivity to a value between 0 and 1, according to the distribution G. The firm has the choice of either continuing to produce at the new productivity, or closing the job down. The idea is that initially firms have a choice over their product type and technique and choose the combination that yields maximum productivity. Over time techniques are not reversible, so if the payoffs from a given choice change, the firm has the choice of either continuing in the new environment or destroying the job.

As in the case where workers are faced with a take-it-or-leave it choices from a given wage distribution, Mortensen and Pissarides (1994) show that when the firm has the choice of either taking a productivity or leaving it, its decision is governed by a reservation productivity, denoted R. The reservation productivity depends on all the parameters of the model. Profit maximization under the Nash solution to the wage bargain implies that both workers and firms agree about the optimal choice of R, i.e. which jobs should be closed and which should continue in operation. With knowledge of R, the flow of job closures generalizes to $\lambda G(R)(1 - u)$, the fraction of jobs that get shocks below the reservation productivity. The job destruction rate then becomes $\lambda G(R)$, which responds to the parameters of the economy through the responses of R to shocks.

An interesting feature of the job creation and job destruction rates, which conforms to observation, is that because the job creation rate depends on unemployment, which is a slow-moving variable, whereas the job destruction rate does not depend on it, the job destruction rate is more volatile than the job creation rate. For example, a rise in general productivity p, associated with a positive cyclical shock, reduces job destruction immediately by reducing the reservation productivity, but increases job creation at first and then reduces it, as tightness rises at first but unemployment falls in response.

5.2 Technological progress and obsolescence

Another way of modeling job destruction borrows ideas from Schumpeter's theory of growth through creative destruction (see Aghion and Howitt 1994, Caballero and Hammour, 1994). Jobs are again created at the best technology but once created, their technology cannot be updated. During technological progress, the owners of the jobs have the option of continuing in production with the initial technology or closing the job down and opening another, more advanced one. As new jobs are technologically more advanced, the wage offers that workers can get from outside improve over time. There comes a time when the worker's outside options have risen sufficiently to render the job obsolete.

Formally, the model can be set up as before, with the technology of the job fixed at the frontier technology at creation time and wages growing over time because of growth in the returns from search. The value of a job created at time 0 and becoming obsolete at T is

$$J_0 = \int_0^T e^{-(r+\lambda)t}[p(0) - w(t)]dt. \quad (32)$$

As before, r is the discount rate and λ is the arrival rate of negative shocks that may lead to earlier job destruction. $p(0)$ is the initial best technology and $w(t)$ the growing wage rate. The job is destroyed when $w(t)$ reaches $p(0)$; i.e. the job life that maximizes J_0 is defined by $w(T^*) = p(0)$.

A useful restriction to have when there is growth is to assume that both unemployment income and the cost of recruitment grow at the exogenous rate of growth of the economy. As an example, consider the wage equation (21) with the restriction $K = 0$ and $b(t) = be^{gt}$, $c(t) = ce^{gt}$, where g is the rate of growth of the economy. T^* then satisfies

$$e^{gT^*} = \frac{(1-\beta)p}{(1-\beta)b + \beta c\theta}. \quad (33)$$

Jobs are destroyed more frequently when growth is faster, when unemployment income is higher and when the tightness of the market is higher.

Job destruction in this model has two components, the jobs destroyed because of the arrival of shocks, $\lambda(1-u)$, and those destroyed because of obsolescence. The latter group was created T^* periods earlier and survived to age T^*, $\theta q(\theta)ue^{-\lambda T^*}$ (note that in the steady state the job creation flow is a constant $\theta q(\theta)u$). Therefore, the job destruction rate now is $\lambda + \theta q(\theta)ue^{-\lambda T^*}/(1-u)$, which varies in response to changes in T^* but also in response to changes in the job creation rate $\theta q(\theta)u/(1-u)$.

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