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Labor search and matching in macroeconomics

Eran Yashiv*

Tel Aviv University, Israel, CEPR, IZA and CEP (LSE)

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Abstract

The labor search and matching model plays a growing role in macroeconomic analysis. This paper provides a critical, selective survey of the literature. Four fundamental questions are explored: How are unemployment, job vacancies, and employment determined as equilibrium phenomena? What determines worker flows and transition rates from one labor market state to another? How are wages determined? What role do labor market dynamics play in explaining business cycles and growth? The survey describes the basic model, reviews its theoretical extensions, and discusses its empirical applications in macroeconomics.

The model has been developed against the background of difficulties with the use of the neoclassical, frictionless model of the labor market in macroeconomics. Its success includes the modelling of labor market outcomes as equilibrium phenomena, the reasonable fit of the data, and—when inserted into business cycle models—improved performance of more general macroeconomic models. At the same time, there is evidence against the Nash solution used for wage setting and an active debate as to the ability of the model to account for some of the cyclical facts.

JEL classification: E24; E32; E52; J23; J31; J41; J63; J64; J65

Keywords: Search; Matching; Macroeconomics; Business cycles; Worker flows; Growth; Policy

1. Introduction

The labor search and matching model has come to play a growing role in macroeconomic analysis. This paper provides a critical, selective survey of the literature. It is

*Tel.: +972 3 640 9233; fax: +972 3 640 7382.
E-mail address: yashiv@post.tau.ac.il

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selective by necessity, as the relevant literature spans almost four decades, with a particularly high volume of papers in recent years.

There are four fundamental questions explored in this literature:

(i) How are aggregate labor market outcomes—unemployment, job vacancies, and employment—determined as equilibrium phenomena? In particular, why do unemployed workers and unfilled vacancies co-exist? These questions are posed with respect to both steady state and stochastic dynamics. Hence, issues of driving shocks, propagation mechanisms, and amplification processes come into play.

(ii) What determines worker flows from one labor market state to another? What determines the transition rates of workers to and from non-employment (unemployment and the "out of the labor force" pool)?

(iii) How are wages determined in this context? In particular, how do wages relate to the state of the market (unemployment, vacancies) and to worker transition rates?

(iv) What role does the labor market, in particular its dynamics, play in explaining business cycles and growth? An example of the former is the question of how worker hiring and separation vary over the business cycle. An example of the latter is the question of the change in unemployment when GDP growth changes: Does higher growth lower unemployment or rather increase it?

These questions are, for the most part, not new and other models address them too.[1] What has been motivating authors using this model to re-explore them?

One concern has been the inability of the neo-classical, Walrasian model of a frictionless labor market to address the afore-cited questions in a satisfactory way. Using the conventional model with an upward-sloping labor supply curve and downward-sloping labor demand curve leads to difficulties in explaining the existence of unemployment (all the more so as an equilibrium phenomenon), in accounting for large and volatile gross worker flows, in explaining worker transitions, and in fitting some of the business cycle facts, such as the low cyclicality of real wages.

The neo-classical model is an element of the standard RBC model. A well-known problem encountered by the latter model is the requirement of high labor supply elasticity that would generate the empirically observed high variability of hours worked together with low real wage variability. But it is hard to justify such high elasticity, particularly given the low elasticity estimates of micro-based studies. This also calls for alternative modelling of the labor market.

A related concern is the difficulty in using a basically static model of the labor market. Labor markets in the real world are not well described as spot markets, which is the maintained assumption in the neo-classical model. Rather, longer term relationships are a prevalent characteristic of these markets. The existence of such relationships is at least partly due to frictions. Frictions prevent the instant formation of employment relationships, a feature of the spot market formulation.

The literature on search and matching tackles these problems. It has relied on observations of the real world to posit the existence of trading frictions. It takes time and resources for a worker and a job vacancy to find each other and to agree on the wage. This formulation naturally leads to the exploration of three key issues: The search process of

[1]For example, the efficiency wage model also caters for equilibrium unemployment. However, this model has empirical difficulties, such as being too stylized to predict outcomes, not being able to match employment volatility, or emphasizing phenomena that are quantitatively small.

unemployed workers and job vacancies; the matching process between them; and the bargaining process, whereby the wage is set. The model places emphasis on the flows between labor market states—employment and non-employment—and allows for a dynamic steady state. Like other key models in modern macroeconomic theory, it has optimizing agents, rational expectations, and equilibrium outcomes. These features allow it to be readily used within DSGE frameworks like the RBC and New Keynesian models and in growth models.

The integration of the search and matching model into a macroeconomic DSGE model allows for the explanation of the level of labor market outcomes (for example, why the steady-state unemployment rate is as high as it is in a given economy) and for the explanation of fluctuations. For the latter, the study of amplification and persistence of driving impulses has been a major issue. The model, through its emphasis on labor market frictions, derives amplification using the employment—non-employment margin rather than the employment—leisure margin; it derives persistence through costly search and time-consuming matching rather than through the assumption of persistence in driving forces (see Hall, 1999 for a discussion of these issues).

The research agenda has gone from mostly theoretical modelling to increasingly empirical explorations, and from a simple, partial equilibrium formulation, including some ad hoc elements, to more complex, general equilibrium models and exploration of micro-foundations for the various elements of the model. The empirical findings gave rise to additional modelling questions and so currently theoretical models are elaborated in response to empirical work.

The empirical studies reviewed below offer some corroboration of the model's key equations and quantitative answers to the first three questions posed above. At the same time there are some empirical failures of the model. With respect to the first question, there is the ability to explain and fit the key outcomes—unemployment and vacancies—and their covariation. For the second question on the determination of flows and transition rates, there is a good sense of how to fit the data on matching flows. On the other hand, there are debates and lingering doubts on separation flow data and their interpretation. For the third question, there has been much empirical difficulty and there is agreement that wage behavior is not well explained by the standard model.

As to the fourth question, accounting for business cycle facts, model performance is very actively debated. On the one hand, some papers show that the model is able to capture the cyclical behavior of key variables, especially that of the labor stocks and flows. On the other hand, a number of studies claim that the model is unable to capture the effects of productivity shocks on labor market outcomes, and that the high volatility of vacancies and unemployment is yet to be explained. Thus, due to the results on the fourth question and more so on the third question, there is still a need for additional empirical explorations and for additional feedback from the empirical work to theory.

As an expression of the enhanced use of the model in macroeconomics, it is interesting to note that as recently as the 1990s the model was absent from most macroeconomic textbooks. Now it is increasingly used; see, for example, the undergraduate textbook of Mankiw (2007, 6th edition, Chapter 6) and the graduate textbooks of Ljungqvist and Sargent (2004, 2nd edition, Chapter 26) and Romer (2006, 3rd edition, Chapter 9.8).

A remark about the relation of this survey to preceding ones is in place: The survey of Rogerson et al. (2005) characterizes three main classes of search models: Random matching and bargaining, directed search and wage posting, and random matching and wage posting. The current survey refers to the first class of models and focuses on exploring its macroeconomic implications. It updates and greatly expands the discussion contained in the survey by Mortensen and Pissarides (1999a), covering the mileage made in the 9 or so years since the writing of the latter. It complements, but does not overlap, the surveys of the micro-based search literature by Mortensen (1986), Mortensen and Pissarides (1999b), and Eckstein and van den Berg (2007). Note, too, that the Pissarides (2000) book provides an excellent overview of the basic model and its main extensions, as well as comments on the literature.

The outline of the survey is as follows: Sections 2 and 3 deal mostly with the theory, while Sections 4–6 discuss empirical issues. Section 7 makes the connection with micro-based studies. Section 8 offers a summary of open questions and concludes.

Section 2 presents the standard model. It starts from the basic elements, goes on to characterize its equilibrium and dynamics, embeds it into a general equilibrium model, and presents the conditions for efficiency. It then points to the specific contributions the model makes to macroeconomic research. Section 3 reviews the major extensions and modifications that have been proposed in recent research.

The formulation and modification of the model have been increasingly informed by empirical studies. Section 4 describes the data relevant for the examination of the model, in particular the study of gross worker flows. It then describes key papers which have estimated the model. This naturally leads to the discussion, in Section 5, of the contribution of the model to the study of business cycles. The latter includes a discussion of recent controversies and debates. Subsequently, Section 6 takes up, more briefly, the role of the model in the study of other macroeconomic questions: Growth, inequality, monetary policy, and labor-market-related policy.

2. The standard model

The antecedents to the development of the basic ideas of the model were made in the Phelps (1967) and Friedman (1968) critique of the Phillips curve and the proposition of the "natural rate" idea. The seminal papers that suggested the search framework were the Phelps (1970) and Mortensen (1970) papers in the celebrated 1970 "Phelps volume." These papers introduced the flow approach to the labor market, search costs, and the idea that the firm's intertemporal choice is akin to investment with adjustment costs. The key papers which have contributed the main building blocks of the model, as described below, are Diamond (1982a,b), Mortensen (1982a,b), Pissarides (1979, 1985), and Mortensen and Pissarides (1994). In this section I briefly sketch out the standard model. The presentation closely follows Pissarides (2000, in particular Chapters 1–3) and, for the most part, uses his notation.

2.1. The environment

There are risk-neutral, infinitely lived workers and firms. There are many such agents so each operates as an atomistic competitor; formally this is often modelled as a continuum on a closed interval. Agents discount the future at rate r and have rational expectations. Firms and workers need to engage in costly search to find each other. Firms spend resources on advertising, posting job vacancies, screening, and, subsequently, on training. Workers spend resources on job search, with costs pertaining to activities such as collecting information and applying to jobs. Workers and firms are assumed to be randomly matched. After matching, the worker and the firm engage in bilateral bargaining over the wage.

The basic model essentially relates to homogeneous workers and homogeneous jobs, so unemployed workers seek identical job vacancies. More complicated versions introduce heterogeneity with workers of different skills or preferences, with jobs of various qualities (such as "good" and "bad" jobs), or with ex-post heterogeneity in matching. This opens the way to on-the-job search and job-to-job movements. In what follows I shall first refer to the basic model before considering various extensions.

2.2. Job–worker matching

The way unemployed workers (denoted by u in terms of rate out of the labor force) and job vacancies (denoted by v in the same terms) meet is modelled as a matching process. The latter is formalized by a "matching function" that takes searching workers and vacant jobs as arguments and produces a flow of matches. It assumes frictions in the matching process such as informational or locational imperfections. As noted by Pissarides (2000, p. 4) "the matching function summarizes a trading technology between heterogeneous agents that is not made explicit." In Section 3.3 below I refer to some work on the micro-foundations of this function.

The matching function is given by

$$m = m(u, v). \tag{1}$$

It is continuous, non-negative, increasing in both its arguments, and concave. Typically it is assumed to be homogeneous of degree 1. If we allow for worker search intensity s this will become

$$m = m(su, v). \tag{2}$$

For simplicity I shall normalize aggregate search intensity at $s = 1$. Its determination by the worker will be discussed below.

It is useful to define a concept of "market tightness," given by the vacancy–unemployment ratio v/u, to be denoted by θ. Using the homogeneity assumption, the vacancy matching rate q is given by $q(\theta) \equiv \frac{m}{v}$ and the job-finding rate, or hazard rate, is given by $p(\theta) \equiv \frac{m}{u}$. The dependence of the rates $q(\theta)$ and $p(\theta)$ on market tightness is related to the externalities inherent in the model. Thus, q falls with v and p falls with u as more agents searching on the same side cause a negative congestion externality, while q rises with u and p rises with v as more agents searching on the other side cause a positive trading externality.

2.3. Match separation

The flow into unemployment results from job-specific (or idiosyncratic) shocks to matches that arrive at a Poisson rate λ. These shocks may be explained as shifts in demand (that change the relative price of the good produced by a job) or by productivity shocks (that change the costs of production). Once a shock arrives, the firm either continues production at the new value or closes the job down.

In the earlier version of the model (for example, Pissarides, 1985), the arrival of a shock leads to the closing down of the job, i.e., the dissolution of the match and to worker separation. Thus, idiosyncratic shocks move the value of the match output from a high level to a low one, at which it is not profitable to operate, at the exogenous rate λ.

In the later version of the model (Mortensen and Pissarides, 1994), the arrival of an idiosyncratic shock makes the net product of the job change to some new value that is drawn from a general probability distribution, not necessarily closing down the job. The job destruction decision (and thus the value of λ) becomes endogenous. I examine this point in detail below.

2.4. Unemployment dynamics and steady state

The evolution of the unemployment rate is given by the difference between the separation flow and the matching flow:

$$\dot{u} = \lambda(1-u) - p(\theta)u. \tag{3}$$

In the steady state, rate of unemployment is constant and given by

$$u = \frac{\lambda}{\lambda + p(\theta)}. \tag{4}$$

This is a key equation of the model. It can be represented in tightness (θ)—unemployment (u) space or in vacancy (v)—unemployment (u) space, by a downward-sloping curve. This theoretical concept is consistent with the empirical relationship known as the ''Beveridge curve.'' The latter is so named following the work of Beveridge (1944) who characterized it in British data.[2]

2.5. Firms' optimization

Each firm i uses K_i and N_i, capital and labor, respectively, to produce output using $F(K_i, \xi N_i)$, a constant returns to scale production function. The parameter ξ is a labor-augmenting productivity parameter.[3] The firm buys capital K_i at the price of its output and pays workers real wage w_i, derived below, which is taken as given by the firm. In the basic model there are no costs of adjustment for capital but adjusting labor involves linear costs; each vacancy costs the firm ξc and matches with a worker at the rate $q(\theta)$, where θ is outside the firm's control.[4]

Each firm i is assumed to maximize expected discounted profits with respect to K_i and v_i:

$$\max_{K_i, v_i} \Pi_i = \int_0^\infty e^{-rt}[F(K_i, \xi N_i) - w_i N_i - \xi c v_i - \dot{K}_i - \delta K_i]\, dt, \tag{5}$$

subject to the evolution of employment, which conforms the matching and separation flows described above:

$$\dot{N}_i = q(\theta)v_i - \lambda N_i, \tag{6}$$

where r is the discount rate, and δ is the rate of depreciation of the capital stock.

[2] See Yashiv (2008) for a discussion of this concept.

[3] The discussion here abstracts from long-run growth issues. For the latter see Pissarides (2000, Chapter 3).

[4] If we denote $K_i/\xi N_i$ by k_i, the relevant derivatives can be written as follows:

$$F_1(K_i, \xi N_i) = f'(k_i),$$

$$F_2(K_i, \xi N_i) = f(k_i) - k_i f'(k_i).$$

Denote by Ψ the co-state variable associated with this constraint, and define

$$f(k_i) \equiv \frac{1}{\xi N_i} F(K_i, \xi N_i) \equiv F\left(\frac{K_i}{\xi N_i}, 1\right), \tag{7}$$

where $\xi f(k_i)$ is output per person employed.

In the steady state ξ, r, Ψ, and θ are constant. Hence the Euler equation for capital is

$$f'(k_i) = r + \delta \tag{8}$$

and the marginal product of labor is given by

$$\xi F_2(K_i, \xi N_i) = \xi[f(k_i) - (r + \delta)k_i]. \tag{9}$$

The relevant steady-state Euler equation for vacancies is

$$\xi c = q(\theta) \frac{\xi[f(k_i) - (r + \delta)k_i] - w_i}{(r + \lambda)}. \tag{10}$$

The LHS are marginal vacancy costs. The RHS are expected, discounted match profits. The equation implies that the marginal product does not equal the wage. Indeed, it is bigger than the wage in order to compensate the firm for the costs of vacancies.

It is useful to cast these equations in ''asset value'' terms. One can define the asset value of a filled vacancy or of a job—to be denoted as J—as these costs (ξc) times the average life of the vacancy (given by $\frac{1}{q(\theta)}$):

$$J \equiv \xi c \frac{1}{q(\theta)}. \tag{11}$$

This allows for the re-writing of (10) for the flow value of a filled vacancy rJ_i as follows:

$$rJ_i = \xi[f(k_i) - (\delta + r)k_i] - w_i + \lambda(V_i - J_i). \tag{12}$$

The job earns $\xi[f(k_i) - (\delta + r)k_i] - w_i$ and with probability λ becomes a vacancy. Note that similarly the flow value of a vacancy can be defined as rV_i and written as

$$rV_i = -\xi c + q(\theta)(J_i - V_i). \tag{13}$$

The vacancy incurs costs ξc while open and with probability $q(\theta)$ becomes a filled job. Assuming free entry, all profit opportunities are used, driving the present value of a vacancy, V, to zero, i.e., $V = 0$. Inserting $V = 0$ in this equation one gets Eq. (11) again.

I shall use these value formulations below when deriving the wage solution.

2.6. Workers' optimization

The worker earns w_i when employed and searches for a job when unemployed at intensity s_i. Search is costly and a convex search cost function is assumed $\sigma_i = \sigma(s_i \ldots)$, where the first two derivatives with respect to s_i are positive and there may be other factors affecting search costs. During unemployment the worker gets z, which represents unemployment insurance (UI), imputed value of leisure, or income from work in the informal sector. The basic model assumes that z is constant and independent of market wages. The worker optimization problem is formulated as follows. Worker i chooses search intensity s_i, facing the job-finding probability given by

$$p_i = \frac{s_i}{s}\frac{m(su, v)}{u}. \tag{14}$$

Using the same flow value formulations as used for the firm (rJ_i and rV_i, see Eqs. (11) and (13) above), the unemployed worker maximizes the present flow value of earnings:

$$rU_i = z - \sigma(s_i \ldots) + p(s_i, s, u, v)(W_i - U_i), \tag{15}$$

where the asset value functions, U_i and W_i, denote the present discounted value of the expected income stream of, respectively, an unemployed and an employed worker. The unemployed worker earns $z - \sigma(s_i \ldots)$ and with probability $p(s_i, s, u, v)$ becomes employed.

Hence optimal search intensity is given by

$$\sigma_s(s_i \ldots) = \frac{\partial p_i}{\partial s_i}(W_i - U_i), \tag{16}$$

where σ_s is the derivative of σ with respect to s. Under conventional formulations for the function σ this yields an interior solution.

Employed workers earn a wage w_i and lose their jobs and become unemployed at the rate λ. Hence the flow value of employment, W_i, satisfies

$$rW_i = w_i + \lambda(U_i - W_i). \tag{17}$$

The term rW_i is the permanent income of employed workers, incorporating the risk of unemployment. The basic model has no on-the-job search, so workers stay in their jobs as long as $W_i \geqslant U_i$. The necessary and sufficient condition for this to hold is $w_i \geqslant z$, for which a sufficient condition is $\xi \geqslant z$, which is assumed.

As all workers are atomistic and homogeneous they choose the same search intensity so $s_i = s$. Using the latter with (14)–(17) the following is derived:

$$\sigma_s(s \ldots) = \frac{w - z + \sigma_s(s \ldots)p}{r + \lambda + p}\frac{p}{s}. \tag{18}$$

Search intensity depends on wages, unemployment income, the probabilities of job finding and separation, the interest rate, and any other variable affecting search costs.

2.7. *Wage bargaining*

In this setup of search costs, a job match yields some pure economic rent, which is equal to the sum of the expected search costs of the firm and the worker (including foregone wages and profits). Wages need to share this economic rent, in addition to compensating each side for its costs from forming the match. The standard model assumes that this rent is shared according to the Nash (1950) solution to a bargaining problem. Bargaining takes place after the firm and the worker meet. Because all jobs are equally productive and all workers have the same unemployment value, the wage fixed for each job is the same throughout the economy. I shall therefore drop the index i. Note that each individual firm and worker are too small to influence the market, so when they meet they take the rest of the market as given. The wage contract is renegotiated whenever new information arrives, i.e., the wage continually satisfies the Nash sharing rule for the duration of the job.

The Nash bargaining solution is the w that satisfies (using W, U, J, and V as defined above):

$$w = \text{argmax}(W - U)^{\beta}(J - V)^{1-\beta}, \tag{19}$$

where $0 \leqslant \beta \leqslant 1$ represents worker bargaining power. For the interpretation of this parameter, see Binmore et al. (1986).

The first-order maximization condition derived from (19) is

$$W - U = \beta(J + W - V - U). \tag{20}$$

Using (11), (15) and (17), and the free entry condition $V = 0$ in Eq. (20), the wage is then given by

$$\begin{aligned} w &= z - \sigma(s_i \ldots) + \beta[\xi(f(k) - (r + \delta)k + c\theta) - (z - \sigma(s_i \ldots))] \\ &= (1 - \beta)(z - \sigma(s_i \ldots)) + \beta\xi[f(k) - (r + \delta)k + c\theta]. \end{aligned} \tag{21}$$

The wage is equal to net unemployment income $(z - \sigma(s_i \ldots))$ plus an expression that gives the worker a fraction β (the bargaining power) of the surplus. The latter consists of current productivity $\xi[f(k) - (r + \delta)k]$ and average hiring costs $\xi c\theta = \frac{\xi c v}{u}$, related to the match future productivity, via the firm optimization conditions, less unemployment income $z - \sigma$. Alternatively, one can view the wage as a weighted average of unemployment income and of current and future match productivity, with weights $1 - \beta$ and β, respectively.

2.8. Steady-state equilibrium

In what follows I present the equilibrium in steady state, distinguishing between the cases of exogenous and endogenous separations.

2.8.1. Exogenous separations

Equilibrium is characterized by a four-equation system as follows (see (4), (8), (10), and (21))[5]:

$$f'(k) = r + \delta, \tag{22}$$

$$\xi c = q(\theta)\left[\frac{\xi[f(k) - kf'(k)] - w}{r + \lambda}\right], \tag{23}$$

$$w = (1 - \beta)z + \beta\xi[f(k) - (r + \delta)k + c\theta], \tag{24}$$

$$u = \frac{\lambda}{\lambda + p(\theta)}. \tag{25}$$

The four equations are solved for the capital to effective labor ratio (k), market tightness (θ), the wage (w), and the rate of unemployment (u) for given values of the interest rate (r), the depreciation rate (δ), unemployment income (z) and the parameters ξ (productivity), c (vacancy costs), λ (separation), and β (worker bargaining power).

[5]This is obtained using the Euler equations, constant ξ, θ, w, N_i, and K_i, and the constraint (6) for $\dot{N}_i = 0$. The firm homogeneity assumption implies that all firms choose the same k_i and so the subscript is dropped.

2.8.2. Endogenous separations

The job destruction decision may be endogenized by considering a more general structure for idiosyncratic productivity shocks. The basic idea is that at some of the idiosyncratic productivities production is profitable but at some others it is not. The firm chooses a reservation productivity and destroys jobs whose productivity falls below it. When job destruction takes place, the firm and worker separate. This generates an endogenous flow of workers into unemployment.

The setup now includes the following elements, denoting by ξx the productivity of the job, where ξ denotes, as before, a general productivity parameter, and x an idiosyncratic one: When an idiosyncratic shock arrives, the productivity of the job moves from its initial value x to some new value x', which is a drawing from a general distribution $G(x)$ with support in the range $0 \leqslant x \leqslant 1$. Note that the model of the preceding subsection can be reinterpreted as one that allowed only two values for the idiosyncratic parameter; 1 and 0. Idiosyncratic shocks arrive to jobs at Poisson rate λ. The idiosyncratic productivity that is drawn after the arrival of the shock is independent of initial productivity and is irreversible. The firm has the choice either to continue production at the new productivity or close the job down and separate from the worker. Likewise, the worker has the option to quit. Because of surplus sharing, the match dissolution decision is always mutual. At job creation, the firm has complete choice of job productivity, so profit maximization requires that all new jobs are created at maximum productivity, $x = 1$.

Mortensen and Pissarides (1994, 1999a) show that this setup generates the following key elements:

Wage bargaining. Wages are set through Nash bargaining, so as before[6]:

$$w(x) = (1-\beta)z + \beta\xi(x + c\theta). \tag{26}$$

Job creation. Job creation is given by

$$(1-\beta)\frac{1-R}{r+\lambda} = \frac{c}{q(\theta)}. \tag{27}$$

Eq. (27) says that the expected gain from a new job to the firm (the LHS) must equal the expected hiring cost that the firm has to pay (the RHS). General productivity ξ does not enter this expression because both the firm's expected revenues and costs are proportional to ξ.[7]

Job destruction. The job destruction condition is given by

$$R = \frac{z}{\xi} + \frac{\beta c}{1-\beta}\theta - \frac{\lambda}{r+\lambda}\int_R^1 (s-R)\,\mathrm{d}G(s). \tag{28}$$

Reservation productivity, R, is less than the flow value of unemployment, rU.[8] The reason for this result is that occupied jobs have a positive "option value," which implies that there is some labor hoarding. This option value is shown by the integral expression in (28). Because of the possibility that a job productivity might change, the firm keeps some

[6]Where in the notation of Eq. (21) productivity x is $f(k) - (r+\delta)k$.

[7]Note that $R \leqslant x \leqslant 1$ as firms will close down jobs with $x < R$, hence the $1 - R$ expression.

[8]This is given by

$$rU = z + \frac{\beta}{1-\beta}\xi c\theta.$$

currently unprofitable jobs occupied. By doing so it is able to start production at the new productivity immediately after arrival, without having to pay a recruitment cost and forego production during search.

Unemployment dynamics. The flow into unemployment is the fraction of jobs that get hit by a productivity shock below the reservation productivity; in a large market this is given by the product of the fraction of firms that get hit by a shock, λ, and the probability that the shock is below reservation productivity, $G(R)$. As before, the flow out of unemployment is equal to matching of unemployed to vacancies. The dynamics of unemployment are therefore given by

$$\dot{u} = \lambda G(R)(1-u) - p(\theta)u \tag{29}$$

and steady-state unemployment is

$$u = \frac{\lambda G(R)}{\lambda G(R) + p(\theta)}. \tag{30}$$

Equilibrium solution. The four equations—(26), (27), (28), and (30)—are used to uniquely solve for the four unknowns in the steady state: Unemployment u, the reservation productivity R, wages w, and market tightness θ, for given values of the variables r and z, the productivity distribution $G(x)$, and the parameters ξ, c, λ, and β.

2.9. Closing the model in general equilibrium

The interest rate r is basically exogenous in the afore-going model. Assuming risk-neutral agents, it is equal to the discount rate of workers. Embedding this model in a GE framework makes it endogenous, and labor market variables are endogenously derived together with other macroeconomic variables, like output, consumption, and investment. Such a framework was proposed by Merz (1995) and Andolfatto (1996), embedding the model in an RBC framework. A key assumption that enables this modelling approach is that each household is perceived as a large extended family which contains a continuum of members. Members in each family perfectly insure each other against variations in labor income due to employment and unemployment. This allows for the modelling of risk averse households and tackles the problem whereby households are identical but not all of their members are employed.

2.10. Efficiency

Hosios (1990) takes the standard model, and building on the insights of Diamond (1982a,b), Mortensen (1982a,b), and Pissarides (1984) on the externalities inherent in the model, derives a set of conditions for constrained Pareto efficient resource allocation. The externalities involved relate to the congestion and trading effects: An additional worker (firm) makes it easier (harder) for vacancies to find workers but harder (easier) for workers to find jobs. The key result is that in the basic model with a CRS matching function, the relevant efficiency condition pertains to the sharing of the match surplus and to the matching function. This condition, which internalizes the externalities, is

$$\beta = \frac{u m_u}{m}, \tag{31}$$

i.e., the worker bargaining power parameter needs to be equal to the elasticity of the matching function with respect to unemployment. In other words, this is the equality of the worker share of the surplus and the worker's contribution to matching. When the worker gets in wages his/her social contribution the equilibrium is efficient. Some models, such as the RBC model discussed above, assume a priori that this condition holds true. It should be noted that some empirical work assumes this too.

2.11. Implications for macroeconomics

The afore-going model provides a useful building block in a more general macroeconomic model. This is so due to the following elements:

(i) It easily fits in with a representative agent macro model.

(ii) Agents are optimizing, have rational expectations, and are forward-looking. In particular see Eq. (5) for firms and Eqs. (15) and (17) for workers.

(iii) Dynamics are considered explicitly, as in the dynamic equation (3) for unemployment and (6) for employment.

(iv) In reference to the four questions delineated in the Introduction, the model shows the following:

(a) Unemployment, employment, vacancies, and wages are determined in equilibrium in both steady state and outside steady state. The model derives these outcomes structurally. For example, Eqs. (22)–(25) describe the steady-state equilibrium with exogenous separations. This equilibrium has the vacancy–unemployment ratio (θ) determined by the condition equating marginal vacancy costs with the marginal profits from vacancies. The vacancy–unemployment ratio is a positive function of productivity net of wages; it is a negative function of vacancy costs and of the two factors serving to discount the present value of the match (i.e., the rate of interest r and the separation rate λ). Finally, equilibrium unemployment is a positive function of the separation rate (λ) and a negative function of the job-finding probability (p).

(b) The flows and transition rates from state to state are determined by matching (see Eq. (1)) and by separation, determined by the reservation productivity rule (see Eq. (28)). The former is a function of unemployment and vacancies; the latter is a function of productivity relative to the outside option of the worker and of future discounted match productivity.

(c) Wages are determined by the Nash bargaining solution as a weighted average of the flow value of unemployment ($z - \sigma$) and current and future productivity. Market tightness θ has a positive effect on wages.

(d) The model implies that shocks to productivity, to the matching process, to hiring costs, to the interest rate or to separations (via idiosyncratic productivity) will act as driving impulses. The frictions—costly search and the matching process—play a role in the propagation and amplification mechanisms. This opens the way to business cycle analysis.

While the model answers all these questions, recent work has found it lacking on several dimensions. From the theoretical perspective, extensions to allow for worker and firm heterogeneity and for micro-foundations of the matching process are the natural steps forward. From the empirical perspective, the aim to fit the data generates the need for more complex formulations of search costs and for the modelling of on-the-job search and alternative wage determination mechanisms. These issues are discussed in the next section.

3. Model extensions

The model can essentially be decomposed into the elements of search, matching, and wage determination. In this section I briefly discuss key extensions of the basic model for each of these elements. Doing so the current research agenda is presented, and wherever relevant, the implications for macroeconomics are noted.

3.1. Firm search

A key aspect of costly search is manifested in firms' hiring costs. The basic model assumes adjustment costs of labor only, modelled as a linear function of vacancies, cv (see, for example, in Eq. (10)). More general formulations allow for convexity of costs, adjustment costs for capital, and interaction between the adjustment costs for capital and those for labor.

Generally, convexity of factor adjustment costs was much studied in the literature on capital adjustment. It was naturally carried over to the labor context, albeit usually for net labor adjustment $(N_t - N_{t-1})$ rather than for the gross flows adjustment considered here.[9] In the search and matching context, convexity of adjustment costs was shown to be empirically relevant in structural estimates reported by Yashiv (2000). His formulation allows for separate cost formulations for posting, advertising, and screening (a function of total vacancies, v) and for training (a function of actual hires, qv). Yashiv (2006a) shows that such a convex formulation is an important ingredient in generating a fit of the model to U.S. business cycle facts. This is so because convex adjustment costs, relative to linear ones, generate two features: They make hiring more sluggish and hence serve to increase the persistence of key variables, and they help generate a negatively sloped $u - v$ curve. Both features correspond to the data.

Den Haan et al. (2000) show that interactions between capital adjustment and the job-destruction rate play an important role in propagating shocks. The mechanism is as follows: A negative productivity shock generates a spike in job destruction, and employment remains persistently lower on account of matching frictions. Lower employment reduces the demand for capital, leading to a lower supply of capital in future periods. The productivity shock thereby reduces the equilibrium capital stock, magnifying the future output effects of the shock. The authors also show that propagation effects are significantly greater when the model is extended to introduce costs of adjusting capital.

Merz and Yashiv (2007) use adjustment costs for gross capital investment, gross hires, and an interaction term between hiring costs and investment costs. Estimating the model for the U.S. economy, they show that this formulation enables the model to jointly explain investment and hiring behavior. This provides a link between the search model and Tobin's Q model of investment. The interaction of labor and capital adjustments is shown to be particularly important for fitting the data, and the estimates imply the optimality of simultaneous hiring and investment. The authors also show that this model can be used to explain stock prices. This link results from the following mechanism: Firms decide on the number of vacancies to post in order to hire workers and on the size of the investment in

[9] Hamermesh (1993, Chapter 6) provides a discussion and presents some evidence. Cooper et al. (2004) provide estimates of plant level and aggregate labor adjustment costs, comparing them and allowing for non-convexities.

physical capital to undertake in their effort to maximize market value. Optimal hiring and investment determine firms' profits—including rents from employment—and consequently their value, as well as the time path of employment and capital. The results show that with estimates of adjustment costs of moderate magnitude, one can characterize such optimal hiring and investment. The implied present values of the latter (hiring and investment) account fairly well for the predicted component of firms' value, over and above the size of the physical capital stock.

These studies suggest that the shape of the firm's hiring costs function is not just a technical issue. The ability of the model to match macroeconomic data hinges on this formulation. While the simple linear formulation used in the basic model is convenient for theoretical analysis, it is insufficient to generate the persistence, volatility, and co-movement features of the data.

3.2. Heterogeneity and on-the-job search

In the basic model all workers and jobs are assumed homogeneous and there is no search on the job. The data show that there are large flows of workers between jobs and the microeconomic search literature has given such transitions an important role. On-the-job search is also likely to have an effect on the wage bargain. One should also be aware of the role played by heterogeneity (workers' skills and preferences, firms' productivities, and skill requirements) for aggregate, macro variables. Hence, it seems natural to incorporate heterogeneity and on-the-job search in the model. The difficulty is to determine the appropriate modelling of heterogeneity, usually cast in terms of worker or match productivity, and bargaining. There is a growing literature in this direction. A key contribution is Mortensen and Pissarides (1994), which is the model with idiosyncratic productivity shocks and endogenous separation rates presented above in Section 2 (see Section 2.9 in particular). In what follows I review other important contributions.[10]

Pissarides (1994) allows for on-the-job search in the standard model. This is enabled by postulating "good" and "bad" jobs, the former being more productive but also more costly to create. Output depends on job-specific human capital, which is accumulated over time. Only the unemployed are prepared to fill vacancies of bad jobs. Workers in bad jobs search for better ones, up to a time limit, set optimally; the limit is due to the fact that workers accumulate sufficient human capital so as to render a move to a better job less profitable. The key decision for firms is how many jobs of each type to bring into the market. In this setup, a positive productivity shock induces more employed workers to search, creating congestion for other workers, and generating a shift of the job composition into more "good jobs," as the latter have a higher flow of applicants. It becomes harder for the unemployed to find work, due to the congestion and the changing job mix. Hence the decline in unemployment following a positive shock slows down. Job vacancies are shown to be more volatile. Krause and Lubik (2004) develop a dynamic general equilibrium model along similar lines. A related contribution is Albrecht and Vroman (2002) who consider a labor market in which workers differ in their abilities and jobs differ in their skill requirements. The distribution of worker abilities is exogenous but

[10]On the job search also arises in models of learning such as those of Jovanovic (1979a,b), Moscarini (2005), and the islands model of Lucas and Prescott (1974). In micro-based models, mostly those with wage posting, on-the-job search is a key feature. These models are discussed below.

the choice of skill requirements by firms is derived endogenously. High-skill jobs produce more output than low-skill jobs, but high-skill jobs require high-skill workers and thus are more difficult to fill. The model uses key ingredients from the standard model to determine the equilibrium mix of job types, along with the equilibrium relationship between worker and job characteristics, wages, and unemployment. Nagypal (2005) considers ex-ante identical firms and workers but assumes the existence of a distribution of idiosyncratic job values for the worker.

Acemoglu (1999) presents a model where firms decide what types of jobs to create and then search for suitable workers. When there are few skilled workers and the skilled–unskilled productivity gap is small, firms create a single type of job and recruit all workers. In response to changes in the skill level of the labor force or technology, jobs open both to skilled and unskilled workers may be replaced by high-quality (capital) jobs designed for the skilled and low-wage jobs targeted at the unskilled. This change in the composition of jobs leads to higher skilled wages, lower unskilled wages, and higher unemployment rates for both skilled and unskilled workers.

Moscarini (2001) develops an equilibrium search-frictional Roy model, which features a continuum of skills and a finite number of job types. The model posits that workers choose types of jobs based on a trade-off between microeconomic incentives, captured by their individual comparative advantage (such as formal education), and macroeconomic incentives (such as unemployment). When unemployment is low and the labor market is tight, workers can afford to wait for the "perfect" job, and comparative advantages matter. Labor mobility across occupations is lower and matching is more successful. In a weak labor market there will be excess worker reallocation due to the higher cost of waiting.

The contribution of these models to macroeconomics is that they offer a characterization of equilibrium outcomes—unemployment, vacancies, wages, hires, separations, etc.—in terms of distributions rather than aggregate or representative agent values. These characterizations, though, depend on the specific formulation of each model, in particular on the information sets of agents, the production technology, the timing structure, and the bargaining protocol. In most cases these are steady-state characterizations only. I return to these points below.

3.3. Matching

There is research which expands on the formulation of the job–worker matching process (Eq. (1)).

One influential approach was developed by Jovanovic (1979a,b, 1984). This is a model where there is gradual learning of the quality of the match, with the match being a pure experience good. A worker's productivity in a particular job is not known ex-ante and becomes known more precisely as the worker's job tenure increases. There is a distribution of worker productivity across different jobs, hence job to job movements (turnover), and an equilibrium wage contract, whereby at each moment in time the worker is paid his or her marginal product, conditional on all available information at that time. Firms contract workers on an individual basis. Turnover is a phenomenon of optimal reassignment caused by the accumulation of better information with the passage of time. The model is designed to explain phenomena related to tenure and turnover, such as wages rising with tenure, and negative correlations of quits with tenure and with wages. When combined with a search model, where also unemployed workers receive job offers, it is able to generate endogenous moves both from job to job and into and out of employment.

Moscarini (2005) brings together the Jovanovic model, which is micro-based, and the Mortensen and Pissarides (1994) model, which takes a macroeconomic equilibrium approach. This is a highly challenging endeavor and is ingeniously achieved by the following three modelling devices: (i) The unknown match quality may take only one of two values; this makes the micro model tractable for aggregation; (ii) wages are set by generalized Nash bargaining, which subsumes the competitive formulation of Jovanovic; (iii) an outside offer to an employed worker triggers a tri-lateral renegotiation problem, and so the two firms play an English auction to win the worker. There are two key results to this model. One is that the resulting equilibrium wage density exhibits the three main features of empirical wage distributions: A unique mode, skewness like a log-normal, and a long and fat right tail of Pareto functional form. The other is that the larger the idiosyncratic productivity uncertainty with respect to match quality, the higher the (Pareto) rate of decay of the upper tail of the wage distribution. The selection of good matches, through optimal quits to unemployment and to other jobs, redistributes mass of workers from the lower to the upper part of the distribution of beliefs about match quality, which determine wages. This explains the skewness and the fat Pareto tail, in spite of symmetric and Gaussian (thin-tailed) noise in output.

The macroeconomic implications of this type of model are explored by Pries and Rogerson (2005). They combine variants of the Jovanovic learning model and the standard model. Job flows are driven by idiosyncratic shocks to job productivity, and worker turnover (in excess of job turnover) is driven by the stochastic accumulation of information about match quality. The Jovanovic model is modified by assuming that match quality is both an inspection good and an experience good. Both parties to a match observe a signal about the match's true quality prior to deciding whether to form a match, and matches form only if the signal about match quality exceeds a threshold value. True quality is revealed over time, but only if a match is formed. Labor market regulations affect worker turnover in the model by influencing hiring practices, that is, the level of the threshold signal. Worker turnover in excess of job turnover results from the desire to create high-quality matches. Hiring practices play an important role in the resource allocation process in this economy: Firms and workers decide how much screening takes place prior to forming a match. The authors show analytically that equilibrium hiring practices are influenced by various labor market policies. These changes in hiring practices will influence observed labor market dynamics and, in particular, will affect measures such as worker turnover and unemployment durations.

Attempts are also being made to go into the "black box" of the matching process. The motivation for these attempts is partly theoretical and partly empirical, i.e., trying to fit the data on the flow of matches. Early formulations used an urn–ball structure, where workers (balls) are randomly assigned to jobs (urns); Butters (1977) introduced the essential idea (see Hall, 1977 for the use in the unemployment context). The random assignment ensures that some jobs are unfilled (yielding vacancies), and some jobs are assigned multiple workers, only one of whom can be hired (yielding unemployment).

More recent developments depart from the idea of random matching. One is the concept of stock-flow matching; Coles and Smith (1998) is a prominent paper in this developing literature. The standard formulation assumes that matched agents are randomly selected from the pool of existing unemployed workers and job vacancies, independently of the duration of search on either side of the match. The stock-flow model emphasizes the systematic elements in search, i.e., non-random matching. In this approach, the role of information is recognized. With the use of information, job seekers have complete information about the location of available vacancies and apply simultaneously to as many they like. Upon contact, the firm and the worker decide whether to form a match and start producing or go back to search. Those who remain unmatched and keep searching do so because there are no trading partners that are suitable for them among the existing pool. An important implication is that no job vacancy or unemployed worker who has been through one round of sampling will attempt to match later with a pre-existing job seeker or vacancy.

Lagos (2000) derives a matching function with micro-foundations. The main difference with the previous modelling is that meeting frictions are not assumed but, rather, are shown to arise endogenously. Agents direct their search and no information imperfections are assumed. The model's spatial structure and the agents' moving decisions are spelled out and prices are assumed to be fixed. The result is that the number of contacts that occur depends on the way agents choose to locate themselves. It is shown that the total number of meetings is a function of the aggregate stocks of searchers on both sides of the market. The paper studies matching behavior with respect to changes in parameters, such as distances between locations, the agents' payoffs, and the sizes of the populations of searchers. Since agents can direct their search, changes in these parameters affect search strategies, altering the shape of the matching function. This analysis suggests an interesting policy implication: The results of policy experiments based on models that assume an exogenous meeting process are likely to be misleading if the random search assumption is not a good characterization of the agents' underlying search behavior. Rather, when agents are able to direct their search, then the matching function is an equilibrium object, sensitive to policy.

In a related setup, Shimer (2007) develops a dynamic model of mismatch. Workers and jobs are randomly assigned to labor markets. Each labor market clears at each instant but some labor markets have more workers than jobs, hence unemployment, and some have more jobs than workers, hence vacancies. As workers and jobs move between labor markets, some unemployed workers find vacant jobs and some employed workers lose or leave their job and become unemployed. The model is shown to be quantitatively consistent with the co-movement of unemployment, job vacancies, and the job-finding rate of unemployed workers over the business cycle in U.S. data.

In another related contribution, Sattinger (2005) applies methods of queueing theory to the analysis of a labor market with frictions. Queueing in a labor market occurs when a worker can get a job by waiting at a firm for a position to become available. Allowing queues benefits firms because labor queues reduce firm vacancies. Unemployed workers can benefit from choosing to queue by reducing the expected time until employment. Unemployed workers search among firms either for a vacancy or for a queue that is not too long. With fairly straightforward assumptions, it is possible to obtain analytical expressions for the expected numbers of firm vacancies, searching workers, and queueing workers for a given aggregate ratio of workers to firms. The results generate a Beveridge curve without the assumption of a matching function. Queueing theory also carries implications for the dynamic adjustment of labor markets with frictions. Changes in unemployment take place mostly through the number of workers in queues rather than through the number of workers actively searching. In a comparison with the standard search and matching model, queueing places limits on the numbers of unemployed workers who are searching. As a result, at higher ratios of workers per firm, the arrival rate is lower when there is queueing.

3.4. Wage determination

Hall (2005a,b) relates to the observed facts whereby there is high volatility of unemployment, vacancies, and the job-finding rate and relative stickiness of wages. Based on these facts, he argues that what needs to be considered is a formulation of wage setting that features no unrealized bilateral gains to trade (i.e., no worker–employer pair has an unexploited opportunity for mutual improvement) and wages that are relatively unresponsive to shocks to the value of a match. Hall (2005a) proposes such an equilibrium sticky-wage model, based on wage determination in terms of a Nash (1953) demand game or auction. The incorporation of wage stickiness greatly increases the sensitivity of the model to driving forces. The stickiness arises in an economic equilibrium and the author explores different equilibrium selection rules to pin down the wage within the bargaining set.

In the context of heterogeneous agents and on the job search, Shimer (2006) shows that the axiomatic Nash bargaining solution is inapplicable. This is so as in this type of environment the set of feasible payoffs is typically nonconvex—an increase in the wage raises the duration of an employment relationship. Looking at strategic bargaining instead, he assumes that when a worker and firm meet they bargain over the wage for the duration of the employment relationship, taking as given the wage bargained by other workers and firms. With homogeneous firms and on the job search, he finds that there is a continuum of market equilibria, each characterized by a different continuous wage distribution. With heterogeneous firms, Shimer provides a simple characterization of market equilibria in which more productive firms pay strictly higher wages.

3.5. Summing up

What, then, is the state of the art? On the one hand, there is by now modelling that takes care of some of the fundamental deficiencies of the standard model. Thus, for instance, there is treatment of heterogeneity (jobs, workers, matches), endogenous separations, interactions with capital investment, learning, and on-the-job search leading to job to job movements, which were absent from the earlier models. On the other hand, there are some new difficulties. For example, with heterogeneity and on-the-job search, there is analytical difficulty in implementing the Nash bargaining solution for wages. Different papers have taken different routes in modelling heterogeneity, the process of on-the-job search, and the derivation of wages. There is no one, accepted model, or one that has been shown to be empirically superior, and what has emerged looks like a loosely connected collection of advanced models. Going forward it seems likely that the ability to match the data may now play a bigger role in the formulation of a more comprehensive model. The earlier models laid down key principles. It is now the time to match the more advanced models with the data and strive for empirically valid formulations.

4. The empirical evidence

I now turn to look at the empirical work related to the search and matching model, which addresses the four questions posed in the Introduction. This work consists of

(i) documentation of facts about key variables in the model; (ii) attempts to see whether the model is consistent with the data; (iii) estimation of the model's parameters, including structural estimation. Evidently, the latter methodology imposes more model-derived restrictions on the empirical examination than the other methods.

By way of introduction to the empirical issues, I discuss the key dynamic equations in Section 4.1. I then look at the data on worker flows and their interpretation in Section 4.2. Next, I survey the estimation of the model: Estimates of the matching function in Section 4.3 and of the full model in Section 4.4. I end the section by drawing the key lessons from the data and estimation work see Section 4.5. While some of the results reported in this section relate to business cycle issues, I leave it to the next section to fully explore the implications of these and related studies for the understanding of business cycles.

4.1. Labor market dynamics

The dynamic equations of the labor market demonstrate what data variables are important for the empirical implementation of the model. These equations recognize that in addition to the official pool of unemployed workers, there is another relevant pool of non-employed workers within the "out of the labor force" category. This pool includes people who are not employed and who are reported as not searching for jobs. Empirically it needs to be taken into account as there are substantial flows between this pool and the pools of employment and unemployment. Hence, while the model recognizes just two states, employment and unemployment, in reality there is an important third state.

The evolution of employment proceeds according to the dynamic equation

$$N_{t+1} = N_t + M_t^{UN+ON} - S_t^{NU+NO}, \tag{32}$$

where N is the employment stock, M^{UN+ON} are gross hiring flows from both unemployment (U) and out of the labor force (O) and S^{NU+NO} are separation flows to these pools. The net flows, in terms of rates, are therefore:

$$\frac{N_{t+1} - N_t}{N_t} = \frac{M_t^{UN+ON}}{N_t} - s_t^{NU+NO}, \tag{33}$$

where $s = \frac{S}{N}$ is the separation rate.

A similar equation holds true for unemployment dynamics:

$$U_{t+1} = U_t(1 - p_t^{UN}) + s_t^{NU} N_t + F_t^{OU}, \tag{34}$$

where U is the unemployment stock, p^{UN} is the hiring rate from unemployment, and F_t^{OU} is the net inflow of workers from out of the labor force, joining the unemployment pool.

This can be re-written as

$$\frac{U_{t+1}}{U_t} - 1 = -p_t^{UN} + s_t^{NU} \frac{N_t}{L_t} \frac{L_t}{U_t} + \frac{F_t^{OU}}{L_t} \frac{L_t}{U_t}. \tag{35}$$

In steady state there is a constant growth rate of unemployment at the rate of labor force growth to be denoted as g^L:

$$\frac{U_{t+1}}{U_t} - 1 = g^L. \tag{36}$$

Thus the unemployment rate is constant at $\overline{u}$:

$$\overline{u} = \frac{U}{L}. \tag{37}$$

Hence steady-state unemployment is given by

$$\overline{u} = \frac{(F^{OU}/L) + s^{NU}}{p^{UN} + g^L + s^{NU}}. \tag{38}$$

In case there is no growth or workers joining from out of the labor force, i.e., $\frac{F^{OU}}{L} = g^L = 0$, this becomes

$$\overline{u} = \frac{s^{NU}}{s^{NU} + p^{UN}}, \tag{39}$$

which is the same equation as (4).

In order to explain employment and unemployment one needs to account for p and s. These variables, as discussed in Section 2, are the product of search and matching. Noting that $M_t = p_t U_t$ and $s_t = \frac{S_t}{N_t}$, the empirical researcher needs data on the stocks U_t and N_t and on the flows M_t and S_t. I turn now to discuss these data and their interpretation.

4.2. Worker flows

I present data sources, the interpretations of these data, and some ensuing controversies.

4.2.1. Data sources

Data on aggregate worker flows in the U.S. come from two main sources: The Current Population Survey (CPS) and the Job Openings and Labor Turnover Survey (JOLTS), both of the Bureau of Labor Statistics (BLS). The CPS was the basis for the analyses of gross worker flows by Blanchard and Diamond (1989, 1990), Ritter (1993), Bleakley et al. (1999), Fallick and Fleischman (2004), Shimer (2005b), Fujita and Ramey (2006), and Elsby et al. (2006). JOLTS data are reported and discussed by Hall (2005b). A summary of data sources and a discussion of them is to be found in Davis et al. (2006). For earlier overviews of data sources on worker flows in the U.S. see Farber (1999) and Davis and Haltiwanger (1998, 1999a).

For descriptions and analyses of gross flows in European countries see Pissarides (1986), Burda and Wyplosz (1994), Van Ours (1995), Contini and Revelli (1997), Albaek and Sorensen (1998), and Layard et al. (2005).

The problems in treating these data and their methods of adjustment, including issues of matching individual responses, misclassification, aggregation across sectors and over time, survey methodology changes, and seasonal adjustment, are discussed in Abowd and Zellner (1985), Poterba and Summers (1986), and in the above papers.

4.2.2. Data interpretation and controversies

Pissarides (1986) examines worker flows and vacancy data to explain the evolution of unemployment in the U.K. He finds that changes in unemployment in Britain have been driven mainly by changes in the rate at which unemployed workers move into employment.

Much of the relevant research focuses on the U.S. economy. The studies cited above indicate that the average monthly matching rate from unemployment ($\frac{M^{UN}}{N}$) is around

1.5–1.7%, and its standard deviation is 0.1–0.3%. The monthly job-finding rate ($\frac{M^{UN}}{U}$) is around 25–32% on average. For flows from out of the labor force there is disagreement across studies; the more recent studies indicate mean hiring rates ($\frac{M^{ON}}{N}$) at 1.3–1.5% and standard deviation of 0.1–0.3%. The monthly separation rate into unemployment (s^{NU}) is around 1.3–1.5% on average, implying quarterly separation rates of around 4%; its volatility is around 0.1–0.3% in monthly terms. The separation rate into out of the labor force is computed differently across the different studies with a monthly mean ranging from 1.5% to 3.2% and a standard deviation ranging from 0.2% to 0.5%. There was an evolution over time in the interpretation of these findings.

Initially, Blanchard and Diamond (1989, 1990) highlighted the finding that the amplitude of fluctuations in the flow out of employment is larger than that of the flow into employment. This, in turn, implies a much larger amplitude of the underlying fluctuations in job destruction than of job creation. Hence, changes in employment are dominated by movements in job destruction rather than in job creation. Another important finding was that there are sharp differences between the cyclical behavior of the flows between employment and unemployment on the one hand and the flows between employment and out of the labor force on the other. In particular, the NU flow increases in a recession while the NO flow decreases; the UN flow increases in a recession, while the ON flow decreases. In a later study, Bleakley et al. (1999) reinforce these conclusions.

More recently, a new and dissenting picture of worker flows, has emerged. Hall (2005b) develops estimates of separation rates and job-finding rates for the past 50 years, using historical data informed by the detailed recent data from JOLTS. He finds that the separation rate is nearly constant while the job-finding rate shows high volatility at business-cycle and lower frequencies. Shimer (2005b) uses CPS data to compute measures of job-finding and separation rates, adjusting for time aggregation. He finds that the job-finding probability is strongly pro-cyclical and the separation probability is nearly acyclical, particularly during the last two decades. He shows that these results are not due to compositional changes in the pool of searching workers, nor are they due to movements of workers in and out of the labor force. Both Hall and Shimer conclude that the results contradict the conventional wisdom, elaborated above. If one wants to understand fluctuations in unemployment, one must understand fluctuations in the transition rate from unemployment to employment, not fluctuations in the separation rate.

This new view has met with counter arguments. Davis (2005), in discussing Hall (2005b), argues that the cyclical behavior of job loss and worker displacement remains a key issue for macroeconomic analyses of labor market fluctuations. Based on his analysis of the data, he concludes that Hall understates the volatility and cyclical movements in the total separations rate and exaggerates cyclical movements in the job-finding rate. Yashiv (2006b) re-examines the data from both the earlier and the more recent studies, finding that there is considerable cyclicality and volatility of both accessions and separations. Hence, both are important for the understanding of the business cycle. He also shows that there are unresolved data problems: Disparities in the measurement of flows between employment and the pool of workers out of the labor force, disagreements on the relative volatility of job-finding and separation rates across data sets, and a mediocre fit of the gross flows data with net employment growth data, differing across studies. Elsby et al. (2006) reconsider the extent to which the increased unemployment during a recession arises from an increase in the number of unemployment spells versus an increase in their duration. Like Hall and Shimer they find an important role for increased duration, but, contrary to them, they point to an important role for increased inflows to unemployment as well. Fujita and Ramey (2006) re-examine CPS data, going back to the initial view: Using the band pass filter to isolate cyclical components, they consider both total worker flows and transition hazard rates. They find overwhelming support for the ‘‘separation-driven’’ view, i.e., that total job loss and hiring rise sharply during economic downturns, initiated by increases in the job loss hazard rate.

Another issue that should be noted in this context are worker flows from job to job. Fallick and Fleischman (2004) studied these flows. They find that they are large; on average, 2.6% of employed workers leave one employer for another each month—about two-fifths of the total number of employer separations. This flow is about the same size as the NO flow and double the NU flow.

4.3. Matching function estimation

The model explains hiring flows and the ensuing job-finding rate with the concept of the matching function (Eq. (1)). Estimation of this function has been widespread. Petrongolo and Pissarides (2001) provide a comprehensive survey of much of this work, finding the following main features: (i) The prevalent specification is Cobb–Douglas with the flow of hires as the dependent variable and the stocks of unemployment and vacancies as the RHS variables; (ii) usually CRS is found, though some studies, such as Blanchard and Diamond (1989) and Yashiv (2000), produce evidence in favor of increasing returns to scale (IRS); (iii) many studies have added other variables—such as demographical or geographical variables, incidence of long-term unemployment, and UI—finding some of them significant, but not changing the preceding findings; (iv) these general patterns are robust across countries and time periods.

These studies suffer, though, from a number of problems: Data quality (especially vacancy data are often of mediocre to poor quality, for example, using an index of Help Wanted Ads rather than number of job vacancies); difficulties in getting consistent measures of the different variables (for example, inclusion or non-inclusion of job to job movers); simultaneity (hiring flows deplete the stocks causing a negative correlation between the explanatory variables and the error term, see Berman, 1997); and serious aggregation issues (geographical and temporal).

Recent literature has begun to address some of these issues. Coles and Smith (1998) and Coles and Petrongolo (2003) provide evidence according to which stock-flow matching functions perform better than random matching formulations.

4.4. Structural estimation

Much of the empirical literature has focused its attention on the estimation of the matching function, as discussed above. There are few papers that relate to the estimation of a broad specification of the model.

Feve and Langot (1996) study the empirical performances of three models of the business cycle: A canonical Walrasian RBC framework, its extension to the case of a small open economy, and a version of this model with search and wage bargaining. Most structural parameters of the models are estimated using GMM with French data and the other parameters are calibrated. The authors compare the moments of the estimated models to the data, finding that only the third model is able to generate theoretical moments that match their empirical counterparts.[11]

Yashiv (2000) uses Israeli data to structurally estimate the model. The findings corroborate the search and matching model's approach whereby vacancy creation and hiring (in the case of firms) and search intensity (in the case of workers) may be accounted for by an intertemporal optimization approach with convex search costs. More specifically, three equations are estimated: (i) The firm's F.O.C (see Eq. (10)), yielding estimates of the costs of hiring the marginal worker or, in other words, the asset value of the match for the firm. The finding is that it ranges between 12% and 22% of average output per worker across specifications, equivalent to 1–2 weeks of wage payments. (ii) The worker's F.O.C (see Eq. (16)) determining search intensity. The estimated search costs are equivalent to 40–65% of monthly wages on average. (iii) The matching function (see Eq. (1)) for both a Cobb–Douglas specification and a trans-log specification. The results show that CRS is rejected with the evidence in the Cobb–Douglas case for IRS in the order of 1.3. The congestion and trading externality effects of search are quantified and shown to covary negatively with the relevant hazard rates (p and q). Plugging in the model's estimated parameters into a partial equilibrium model and simulating, the paper demonstrates the usefulness of the model in accounting for the dynamics in unemployment.

As mentioned (in Section 3.1), Merz and Yashiv (2007) structurally estimate the optimality conditions for firms decisions in U.S. data. The estimates show a good fit of the data, demonstrating that a convex function that allows for the interaction of hiring and investment costs, is both necessary and useful. They find that total hiring and investment adjustment costs are 2.3% of GDP. The marginal costs of hiring, including the interaction with capital adjustment costs, are equivalent to two quarters of wage payments.

An alternative to structural estimation are calibration–simulation studies that setup the model using specific functional forms, assign values to the parameters, specify the driving shocks, and then simulate the model's second moments comparing them with the data. By their very nature, these studies are geared to explain business cycle behavior. In the next section, I review these models.

4.5. *The emerging facts*

The facts that emerge from these studies may be summarized as follows:

(i) Rates of hiring into employment and of separation from employment are counter-cyclical for flows between unemployment and employment, pro-cyclical for flows between out of the labor force and employment, and counter-cyclical for aggregate flows.

(ii) Job-finding rates are pro-cyclical.

(iii) In terms of volatility, hiring rates (but not job-finding rates) are of the same order of magnitude as rates of separation from employment.

(iv) Despite disagreements noted below, the volatilities of job finding and separation from employment in the aggregate (UN + ON and NU + NO) flows are also similar.

[11]This analysis is somewhat similar to those of Merz (1995) and Andolfatto (1996) reviewed below. The differences are that the latter authors study the U.S. economy and use calibrated rather than estimated values for the parameters.

(v) All these rates—hiring, job finding, and separations from employment—are highly volatile.

Taken together these facts imply that there is considerable cyclicality and volatility of both accessions and separations. Hence, both are important for the understanding of the business cycle.

At the same time there is disagreement on the computation and behavior of some key variables:

(i) There are basically two contradictory views as to the volatility of job finding and separations from employment across data sets: Some data sets, notably the Blanchard and Diamond (1989) data set, show that separation rates are much more volatile than job-finding rates; others, notably the Shimer (2005b) data find that the reverse holds true.

(ii) There are differences in measuring and interpreting worker flows, even when using the same data source. For example, while flows between employment and unemployment are measured similarly across studies, flows between N and O are not and the data are only partially consistent with micro-based studies. Also, the fit with net employment growth data differs across studies and is not high.

These discrepancies and inconsistencies are probably due to different methods of treating the data. Hence only further study of the raw data, paying more attention to consistent adjustment, may lead to the creation of more credible data sets.

There are three key lessons from this section.

First, while a number of recent papers have argued that the main variability in labor market outcomes is due to volatility in the job-finding rate and that it is the latter variable that matters most for unemployment dynamics, both the older and the very latest studies indicate that separations matter no less. At this stage, it can be stated that the majority of studies indicate that both hiring and separations are important. This is particularly so for separations out of employment.[12]

Second, while some facts can be agreed upon—pro-cyclical job-finding, counter-cyclical separations from employment, high volatility of all series—there are inconsistencies across data sets, especially relating to the measurement of flows between unemployment and out of the labor force.

Third, the studies estimating the model yield reasonable parameter values for the matching function, the hiring costs function, and the worker search costs function. They show that the model is able to fit the relevant data series, in particular matching flows and search variables (vacancies, worker search intensity).

The studies reviewed offer some empirical corroboration of the model's key equations and provide empirical answers to the first three questions posed in the Introduction. In particular, the second question on the determination of flows and transition rates is by now extensively treated. There is, for example, a good sense of how to fit the data on matching flows. On the other hand, there are debates and lingering doubts on separation flow data and their interpretation. When moving to the fourth question, accounting for business cycles, one learns that the issues of flows and transitions are vitally important for the understanding of cycles. The next section deals with these subjects.

[12]Part of the contradictions between studies stem from the difference between looking at total separations, including the sizeable job to job flows, versus looking just at separations from employment.

5. Business cycle analysis

Search and matching models have become key elements in macroeconomic models that seek to explain cyclical fluctuations in aggregate economic activity. At the same time that the basic model was being formulated in the late 1970s and early 1980s, there were major developments in business cycle research, with the advent of real business cycle models. Given the focus in the search and matching model on the "real" side of the economy, and its use of optimizing agents with rational expectations and equilibrium concepts, the standard model fits well with the RBC research program. Indeed, in the 1990s a number of studies have shown its empirical usefulness in this context. More recently, however, some questioning has emerged with respect to the model's ability to match the data and various modifications and extensions are being explored to cater for that. Concurrently, the model is also used in conjunction with other models of the business cycle. As there is by now a voluminous literature on this topic, in what follows, I survey the main contributions in chronological order, as each has built on the previous contributions to make its point. The emerging picture is a complex one, with both successes and failures. Note that one key difference between the issues examined here and the cyclical facts of worker flows discussed above is that in the current section the question of driving impulses comes into play. A major concern is whether the model is able to adequately link the impulses with the outcomes.

5.1. Early contributions

Within the framework of the standard model presented in Section 2, Pissarides (1985, 1987) provides an analysis of cyclical behavior. This analysis did not pursue the development of a full model of the business cycle, but rather aimed at explaining the dynamic behavior of unemployment, vacancies, and wages, ignoring capital. It tried to match the stylized fact whereby when the economy is off the Beveridge curve it traces anticlockwise loops around the curve. The dynamic system is a saddlepoint, arising because one of the variables, unemployment, is sticky and stable, whereas the other, vacancies, is forward-looking and unstable. In this analysis, a rise in productivity causes an immediate rise in both market tightness and wages, and the two variables jump to their new equilibrium. Firms open more vacancies to take advantage of the higher productivity, setting in motion unemployment dynamics, which move the economy toward the new steady-state equilibrium. Vacancies and unemployment trace anticlockwise loops around the Beveridge curve.

In another early model of cyclical fluctuations with search, Wright (1986) demonstrated how unemployment persistence can be generated even by i.i.d. shocks due to search. The essential mechanism is that workers sometimes choose to wait for a better wage offer, staying unemployed.

5.2. RBC models

A number of papers have shown that the model is useful in accounting for business cycle facts within the RBC approach.[13] Note that the standard RBC model has encountered

[13]For recent surveys of the RBC model, see King and Rebelo (1999) and Rebelo (2005).

some well-known problems. Amongst other issues, it requires the specification of driving shocks to mimic key dynamics in the data and it does not capture well the second moments of some of the key variables. Merz (1995) and Andolfatto (1996) have shown that incorporating the search and matching model in the RBC framework improves on this performance. The improved results consist of the following: Productivity leads employment, as in the data, because the presence of frictions affects the dynamics of labor adjustment; the model conforms the higher volatility of total hours relative to wages, as found in the data; the persistence of employment and unemployment matches the data better; and the dynamics of output in the model are different from the assumed impulse dynamics. With the wage not equal to marginal productivity, the labor share in income is no longer constant but is counter-cyclical, as in the data. However, there remain problems on other dimensions: The model underpredicts the volatility of vacancies; productivity remains more strongly pro-cyclical than it is in the data, though the problem is mitigated relative to the standard RBC model; and the model fails to produce the strongly negative correlation between unemployment and vacancies, the "Beveridge curve" (in fact, under some specifications, it even yields a positive correlation).

Den Haan et al. (2000) have additionally considered endogenous job destruction. They showed that cyclical fluctuations in the job-destruction rate magnify the output effects of shocks, as well as making them much more persistent. Propagation effects were shown to be quantitatively substantial when the model is calibrated using job-flow data, and incorporating costly capital adjustment leads to significantly greater propagation.

Working within a similar framework, Barlevy (2002) uses on-the-job search and endogenous separations to study the issue of job reallocation in recessions. The background for his work is the Schumpeterian notion that recessions are times when resources can be reallocated to more efficient use. The work of Caballero and Hammour (1994), as a notable example, had previously shown that recessions have a "cleansing effect." This idea seemed to have support in the data on increased job reallocation in U.S. manufacturing during recessions (see Davis and Haltiwanger, 1999a,b). Barlevy (2002) claims that while there is such an effect with the closing down of inefficient jobs in recessions, there is a contradictory "sullying effect" at the same time. The latter is due to the fact that during recessions workers reallocate into their more productive employment more slowly and the mass of the job distribution shifts toward matches with lower surplus. Hence, as the economy cleanses out its most inferior matches, more workers are stuck in mediocre matches, and fewer high quality matches are created. He undertakes a simulation exercise suggesting that the sullying effect is the quantitatively more important effect.

5.3. Recent questioning

More recently, some studies have raised questions with respect to the ability of the search and matching model to account for key business cycle facts.

Cole and Rogerson (1999) found that the model can account for business cycle facts only if the average duration of unemployment is relatively high (9 months or longer), substantially longer than in the data Veracierto (2002) has shown that the model fails to simultaneously account for the observed behavior of employment, unemployment, and out of the labor force worker pools. In particular, employment fluctuates as much as the labor force while in the data it is three times more variable, unemployment fluctuates as much as output while in the data it is six times more variable, and it is acyclical while in the data it is strongly counter-cyclical. His model makes an explicit distinction between unemployment and out of the labor force and most of the variations in employment are reflected in fluctuations in labor force participation instead of unemployment. This is so because agents enjoy more leisure being out of the labor force than being unemployed and because it is relatively easy to find employment. Thus, when workers decide to enjoy leisure they choose to leave the labor force instead of becoming unemployed. This feature generates the counterfactual labor market dynamics. Fujita (2004) conducted empirical tests showing that vacancies are much more persistent in the data than the low persistence implied by the model. Costain and Reiter (2003) argue that in an RBC model with matching, pro-cyclical employment fluctuations occur when match productivity rises in booms. At the same time, an increase in unemployment benefits negatively affects employment by reducing the match surplus. They then show that the standard model implies a close relationship between the two, but that this is strongly at odds with data. To reproduce business cycle fluctuations, matching must be quite elastic with respect to the surplus; but to reproduce the observed effects of unemployment benefits policies, matching must be, at the same time, more inelastic.

Shimer (2005a) showed that the standard search and matching model can explain only a small fraction of cyclical fluctuations in the labor market, most notably those of unemployment and vacancies. The key reason for this result, which attracted much attention, is that the standard model assumes that wages are determined by Nash bargaining, which in turn implies that wages are "too flexible." Thus, for example, following a positive productivity shock wages increase, absorbing the shock and thereby dampening the incentives of firms to create new jobs. In the U.S., the standard deviation of the vacancy–unemployment ratio is almost 20 times as large as the standard deviation of average labor productivity, while the model predicts that the two variables should have nearly the same volatility. A shock that changes average labor productivity primarily alters the present value of wages, generating only a small movement along a downward-sloping Beveridge curve.

5.4. *Recent replies*

Several studies have addressed the critique of the afore-going papers.

Mortensen and Nagypal (2007) review in detail the elements of the model that may be "responsible" for the failures found in matching the data and survey some recent work in this context. They make several points: First, they show that the important parameters determining the response of the vacancy–unemployment ratio to a productivity shock are the elasticity of the job-finding rate and the opportunity cost of employment. The former is given by the relevant parameter of the matching function and the latter by the modelling of unemployment income. They offer some discussion of these parameters, disputing the magnitudes used by Shimer (2005a). Second, they argue that a flexible wage per se is not the principal problem with the model. It is the large difference between labor productivity and the wage (i.e., the value of $\xi - w$ in the notation of Section 2), implied by the assigned magnitudes of the parameters, that is responsible for the lack of amplification of productivity shocks. Even if the wage were rigid, its level must be such that the future flow of quasi-rent attributable to the creation of a new job is very small if the model is to account for the volatility of the vacancy–unemployment ratio observed in the data. In other words, a wage that only weakly responds to productivity shocks can account for the observed volatility in the job-finding rate but only if its level is high enough. This discussion implies that various elements that potentially influence the value of $\xi - w$ are important. Third, and following the last point, they augment the model by allowing for capital costs, counter-cyclical involuntary separations, and the less cyclical wage implied by a strategic bargaining outcome. After accounting for all these facts, they find that the amended model can explain about 40% of the volatility in the job-finding rate relative to that of productivity observed in Shimer's CPS data.

Hagedorn and Manovskii (2005) argue that Shimer's choice of the opportunity cost of employment is too low because it does not allow for the value of leisure or home production forgone when employed as well as an unemployment benefit.[14] They calibrate both the opportunity cost of unemployment and the wage share parameter to match the cyclical response of wages and the average profit rate. Using this different calibration, the model does match the data. The problem with this analysis—as pointed out by Mortensen and Nagypal (2007)—is that the authors assume an extremely low value for the gap between wages and unemployment income (less than 2%).

Yashiv (2006a) shows that if there is data-based modelling of the separation rate and if convex hiring costs are allowed for, then for the most part the model fits U.S. labor market data relatively well. This includes capturing the high persistence and high volatility of most of the key variables, the negative covariation of unemployment and vacancies (the ''Beveridge curve''), and the behavior of the worker job-finding rate. He argues that the lack of fit found in the literature is due to the use of a linear hiring cost function instead of a convex one and due to different stochastic properties assigned to the separation rate. As to the former point he shows that when moving back from convex to linear ones the model would indeed perform worse: All the persistence statistics decline, employment volatility falls, wages become counterfactually more volatile, and hiring and separation rates become more disconnected. The other element is the role played by the separation rate. As it is a variable with a relatively high mean, it is the main determinant of the discount factor of the match present value; as it has relatively high volatility and persistence, it makes this present value of the match volatile and persistent. This in turn engenders the volatility and persistence of vacancies, hiring, and unemployment. However, Yashiv, too, finds that the model is unable to account for real wage behavior.

5.5. Summing up the empirical performance of the model

In terms of the questions posed in the Introduction, this section has dealt with the fourth one. Model performance on this topic is actively debated. On the one hand, some papers show that the model is able to capture the cyclical behavior of key variables, especially that of the labor stocks and flows. Matching function estimation, structural estimation of the whole model, and its incorporation in RBC models yield satisfactory results. On the other hand, a number of studies claim that the model is unable to capture the effects of productivity shocks on labor market outcomes, and that the high volatility of vacancies and unemployment is yet to be explained. There is agreement that wage behavior is not well explained.

The research agenda on the open questions is as follows: In terms of data, there is a need to sort out the contradictions across data sets of worker flows. In terms of taking the model

[14]See also the earlier contribution of Costain and Reiter (2003).

to the data, there is a debate as to what is really needed to advance the empirical capabilities of the model. One route is to formulate shocks differently, for example to reformulate the productivity shock process that leads to separations. A second way would be to use different parameter values in the current structure, if micro-based research were to produce such values. A more radical route would be to make fundamental changes in the structure of the model. This can pertain to the matching process, to the modelling of search costs, or to the modelling of wage setting. These explorations are likely to be informed by the development of additional data sets, such as data on gross worker and job flows, and matched employer–employee data sets.

6. Other macroeconomic issues

I briefly examine other macroeconomic issues that have been treated using the search and matching model.

6.1. Growth

Growth causes destruction of old jobs when new technologies arrive, but these are subsequently replaced by new, more productive ones. Pissarides (2000, Chapter 2) discusses the capitalization effect, whereby an increase in growth raises the capitalized returns from creating jobs, and consequently causes a reduction in equilibrium unemployment. Aghion and Howitt (1994) propose an additional consideration. They examine the effects of growth in a variant of the standard model, whereby growth arises from the introduction of new technologies that require labor reallocation for their implementation. They highlight two competing effects on long-run unemployment. The first is the afore-mentioned capitalization effect. The second is a creative destruction effect, whereby an increase in growth lowers the duration of the job match, thereby causing an increase in equilibrium unemployment both through the rise in job separation and through the discouragement of the creation of job vacancies.

Mortensen and Pissarides (1998) embed this discussion in a general equilibrium model in which the number of jobs is determined by the interaction of job-creation and job-destruction decisions. In their model, new technology embodied in capital equipment can be adopted either through destruction of existing jobs and the creation of new ones, or by costly renovation, updating the job's equipment. Under the assumption that the destruction of jobs generates worker layoffs, they show that higher productivity growth induces lower unemployment when renovation costs are low, but that the response of employment to growth switches from positive to negative as the cost of updating existing technology rises above a unique critical level.

6.2. Wage inequality

Models of search that explain wage inequality are at the heart of the micro-based search literature, which is briefly discussed in the next section. In the context of the macroeconomic literature there is much less treatment of this issue. The notable exceptions are the models with heterogeneity and on-the-job search, and in particular, the models of Acemoglu (1999), Albrecht and Vroman (2002), and Moscarini (2005) discussed above. A paper that is specifically devoted to this issue in the macro context is Wong (2003).

It asks whether the standard model with productivity changes can explain wage inequality in the U.S. during the 1970s and 1980s. The key finding is that the model produces counterfactual results. The main sources of failure seems to be exogenous, random matching and/or the exogenous surplus share, neither of which allows firms to use wage policies (such as contracts) to direct workers' search.

Hornstein et al. (2007) calibrate the standard model and find that it can generate only a small amount of wage dispersion due to frictions. This means that wage differentials induced purely by search frictions are very small. Looking at the ratio between the average wage and the lowest wage paid, they find that the data exceeds the model's prediction of a ratio of 1.036 by a factor of 20. The conclusion is that either the model does not explain the data on the cross-section of wages and needs to be modified, or that the model is right, frictions account for a very small part of wage dispersion, and the latter should be attributed mostly to unobserved skills.

6.3. Monetary policy

Some recent papers look at the effects of monetary policy using the search model. Walsh (2005) poses the following key questions: What accounts for the significant real effects of monetary policy shocks and for the persistent and hump-shaped responses of output and inflation to such shocks? It turns out that the answer depends on the presence or absence of particular modelling features.

Walsh (2005) investigates these questions in a model that incorporates labor market search, habit persistence, sticky prices, and policy inertia. While habit persistence and price stickiness are important for the hump-shaped output response and the long, drawn-out inflation response, respectively, labor market frictions increase the output response and reduce the inflation response relative to an otherwise similar model based on a Walrasian labor market. In a similar GE model, Trigari (2004) structurally estimates a set of parameters characterizing the dynamics of the labor market. The results indicate that when labor market search is incorporated into a standard New Keynesian model, the ability of the model to explain the response of output and inflation improves along a number of dimensions. Allowing for variation of the labor input at the extensive margin leads to a significantly lower elasticity of marginal costs with respect to output. This helps to explain the sluggishness of inflation and the persistence of output after a monetary policy shock. The ability of the model to account for the joint dynamics of output and inflation relies on its ability to explain the dynamics in the labor market. The estimated model can also explain the cyclical behavior of employment, hours per worker, job creation, and job destruction, conditional on a shock to monetary policy.

Using a specification which lacks habit formation in consumption and adjustment of hours of work, Krause and Lubik (2007) report a different set of results. They find counterfactual labor market dynamics in the New Keynesian model with sticky prices and search and matching frictions. Introducing real wage rigidity helps explain the labor market facts but does not explain inflation dynamics and the persistent effects of monetary policy. This is so because as wages become more rigid, the cost of hiring workers becomes more volatile. The overall real rigidity remains almost unchanged.[15]

[15]It is the interaction of habit in consumption with adjustment of hours of work that makes the Walsh and Trigari models perform better than the Krause and Lubik model.

6.4. Macroeconomic policy implications

Much of the literature on policy implications of the model deals with two sets of issues:
(i) The effects of specific policy schemes, such as unemployment benefits, payroll taxes, firing taxes, hiring subsidies, and minimum wages, on labor market outcomes.
(ii) Reasons for U.S.–Europe differences in labor market outcomes, such as unemployment incidence and duration, employment growth, wages, earnings inequality, and job and worker turnover.

There is a large number of papers on these issues. Here I look at a few, key studies; these cite and review previous studies, which are not surveyed.

Using a GE search framework, Ljungqvist and Sargent (1998) study the interaction of greater economic turbulence and high unemployment benefits to explain the European unemployment experience. Workers accumulate skills on the job and lose skills during unemployment. The welfare economy is vulnerable to economic turbulence in that, following large shocks, the provision of generous benefits hinders the restructuring of the economy. This is so because laid off workers lack the incentives to quickly accept new jobs with new skills.

Mortensen and Pissarides (1999c) use their model with endogenous separations (Mortensen and Pissarides, 1994) to show that skill-biased shocks can explain why and how different UI and employment protection (EP) policies can lead to the differential U.S. and European wage and employment responses.[16] They use the model to derive a convex, negative relationship between unemployment rates and worker skill levels. The underlying reason for this relationship is that the economic value of unemployment (other than UI) does not rise proportionally with skill. Hence, less-skilled workers experience higher unemployment. This relationship is more convex with relatively high UI and EP levels, as is the case for Europe. They then interpret a skill-biased shock as a mean-preserving increase in the spread of labor productivities across workers, leading to higher average unemployment. Under the European policy parameters, unemployment rises more because of the higher convexity.

Marimon and Zilibotti (1999) consider a model with two-sided, ex-ante heterogeneity. They consider the effects of skill-biased technological change with different levels of unemployment benefits. The latter are perceived as a subsidy for the unemployed to search for a suitable job. When benefits are too high, workers become too selective, rejecting matches that would have been socially efficient. There is a tradeoff between unemployment and mismatch. When the economy is hit by a skill-biased technological shock, the European-type economy with high benefits experiences higher unemployment with longer average duration but also higher worker productivity growth and less wage inequality.

Yashiv (2004) asks how policy affects key labor market outcomes in the steady state, given frictions, and what effects does it have on their business cycle properties. He explores the decline in unemployment following the implementation of different policy measures, the "cost-effectiveness" of each measure, and the changes in the stochastic behavior of unemployment and other key outcomes that follow each policy. He finds that hiring subsidies and unemployment benefits have substantial effects on labor market outcomes, while employment subsidies and wage tax reductions do not. These results are consistent with the view that high European unemployment is due to high hiring costs and generous

[16] See also Millard and Mortensen (1997) for an earlier treatment.

unemployment benefits. Policy also has effects on the stochastic behavior of key variables: Measures that reduce unemployment also reduce its persistence and increase the volatility of vacancies.

Pries and Rogerson (2005) examine four policies—minimum wages, unemployment benefits, firing costs, and taxes—and assess the quantitative impact of European-style policies on allocations and welfare in a calibrated version of the model. They find that minimum wages and firing costs both significantly affect worker turnover. Their analysis also shows that interactions between the various policies can be significant: The effects of minimum wages on hiring practices are exacerbated by the presence of payroll taxes, even though payroll taxes by themselves have very little effect. The model can account for almost half of the observed differences in worker turnover rates between the U.S. and continental Europe. The welfare costs of lowering worker turnover via changes in hiring practices are significant. The steady-state welfare cost of a policy that lowers worker turnover by 20% exceeds 2.4% of output. Although more stringent hiring practices increase the average match quality, they also necessitate that a greater fraction of output be devoted to recruiting.

It should be noted (without review) that there is another strand of literature that looks at the effects of policy on job reallocation, with some elements of search. This strand includes work by Hopenhayn and Rogerson (1993), Bertola and Rogerson (1997), and Alvarez and Veracierto (2001).

7. Relation to the micro-based search literature

This section briefly references the wide array of other search models.

There are search models that share some common features with the model described here, yet differ from it on several dimensions. Closest in spirit, perhaps, is the Lucas and Prescott (1974) model. This is an ‘‘islands’’ model of spatially separated labor markets. Agents work at the market-clearing wage of their own market or move to another labor market. The frictions are due to the fact that moves between markets take time and there is unemployment for that reason. In equilibrium agents move to markets that experience positive productivity shocks, with bad productivity markets losing some of their labor. This model has no matching or bargaining, and wages are set competitively so they equal the marginal product. More recent models following this approach include Greenwood et al. (1996) and Gomes et al. (2001).

There is a vast micro-based search literature. Using the classification of the Rogerson et al. (2005) survey mentioned above, this is the third class of models, relying on random matching and wage posting. The latter survey, and the surveys by Mortensen (1986), Devine and Kiefer (1991), Mortensen and Pissarides (1999b), and Eckstein and van den Berg (2007) provide good overviews. The model with search, random matching, and bargaining surveyed in the current paper differs in three major ways from the micro-based models: The basic model here has no match-specific heterogeneity, the job arrival rates are functions of unemployment and vacancies through the matching function, and there is ex-post wage bargaining rather than wage posting. Because of the first property there is only one equilibrium wage in the basic model, though the more advanced versions with heterogeneity do feature a wage distribution. In contrast, the micro-based models are designed to explain wage distributions, both offered and actual (accepted), and the distributions of employment and unemployment spells. Thus, the micro-based literature focuses on modelling heterogeneity, the optimality of firm wage posting policy and of worker job acceptance, on-the-job search, and the effects of search decisions on the wage distribution and on the unemployment spell distribution. As can be seen in the current survey, some of these issues are now being treated in the matching and bargaining literature as well. But, as indicated, the latter takes a different approach to the modelling of the way workers and firms meet (matching) and set wages (bargaining).

8. Open questions and conclusions

The success of the model thus far relates mostly to the first two questions delineated in the Introduction. It explicitly models labor market outcomes—unemployment, employment, job vacancies, worker flows and transitions—as equilibrium outcomes and estimation work has shown a reasonable fit of the data. Moreover, the advent of the model has encouraged the development of relevant data sets. With respect to the third question, there is a growing sense that the way wage setting has been modelled, using the Nash bargaining solution, is unsatisfactory. This way of modelling has found little empirical corroboration and has proved problematic theoretically too. Current research focuses on the exploration of alternative wage setting mechanisms. As to the fourth question, there is an ongoing debate on the ability of the model to account for business cycle facts. Some studies have shown that it can explain key cyclical facts and improve upon the performance of leading business cycle models, in particular the RBC model. Others studies have pointed to difficulties in matching the data, in particular the high volatility of unemployment and job vacancies and, concurrently, the relatively low volatility of real wages and productivity.

The latter point and other aspects discussed in this survey have demonstrated that there is a substantial number of issues still open that call for further research. In fact, this statement pertains to almost every aspect of the model. There is a need to broaden the firm optimality problem, taking into account the adjustment of other factors of production, as well as the associated costs and lags. Likewise, workers decisions on search intensity seem to be under-researched, in particular empirically. A great need exists for the further modelling of firm and worker heterogeneity. There is ample empirical evidence to show the importance of heterogeneity in other macroeconomic contexts and it underlies the micro-based search literature. The modelling thus far is often stylized (such as "good" and "bad" jobs) and typically has not catered for empirical features, such as highly skewed productivity distributions. On the worker side, labor force participation decisions, reflecting underlying dispersion in preferences and in skills, have not been extensively studied. These modelling issues have a bearing on the matching function. The latter has received much empirical attention, but there is insufficient work on its micro-foundations, especially when recognizing heterogeneity in an explicit way. There is also a need to sort out the relevant data issues, given that there is no agreement on the interpretation of some of the main data series, such as job-finding rates, and hiring and separation flows. All of these modifications are sure to influence the empirical performance of the model when embedded in general equilibrium frameworks. The emergence of new data sets of worker and job flows and matched employer–employee data are likely to facilitate the empirical endeavor.

Despite the fact that much research still needs to be undertaken, it is clear that the model has the ability to explain labor market outcomes, including their dynamics. It enhances our understanding of business cycles and of the effects of policy. It points to the data that we need to consider when studying cyclical fluctuations or the evolution of unemployment. Given the model's richness, it is not surprising to find, as pointed out at the outset, that it has become a key and important feature of macroeconomic modelling.

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