DISCUSSION PAPER SERIES

No. 2749

MACROECONOMIC POLICY LESSONS OF LABOUR MARKET FRICTIONS

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INTERNATIONAL MACROECONOMICS

Centre for Economic Policy Research

www.cepr.org

ISSN 0265-8003

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Discussion Paper No. 2749
March 2001

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ABSTRACT

Macroeconomic Policy Lessons of Labour Market Frictions*

The Paper explores the consequences of macroeconomic policy for labour market outcomes in the presence of frictions. It shows how policy may be useful in overriding frictions, as well as how it might generate adverse outcomes. The analysis looks at the main tools of macroeconomic policy and pertains to both the steady-state and business cycle fluctuations. A partial equilibrium, empirically grounded model is used to simulate policy effects. It relies on a reduced-form VAR of the actual data to specify the effect of exogenous variables, precluding the possibility that labour market results will be affected by misspecifications in other parts of a more general macroeconomic model. The Paper shows how policy affects the natural rate of unemployment and other key outcomes, such as unemployment duration, wages, and the asset value of the job–worker match. Effects on the persistence, co-movement and volatility of the major variables along the business cycle are discussed, demonstrating how policy affects rigidity in the labour market.

JEL Classification: E24, E32
Keywords: Beveridge curve, labour market frictions, macroeconomic policy, matching, search, the natural rate of unemployment, wage bargaining

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*I have benefited from useful comments by Dani Tsiddon and Michel Strawcyznski. I am grateful to Craig Burnside for software and advice and to Michael Ornstein for able research assistance. Financial assistance by the Sapir Forum is gratefully acknowledged. Any errors are my own. This paper is produced as part of a CEPR Research Network on ‘Specialization Versus Diversification: The Microeconomics of Regional Development and the Spatial Propagation of Macroeconomic Shocks in Europe’, funded by the European Commission under the Research Training Network Programme (Contract No: IMRTN HPRN-CT-2000-00072).

Submitted 01 February 2001

NON-TECHNICAL SUMMARY

It is of major interest for policy-makers to know what is the effect of their actions on unemployment, employment, wages, job vacancies and other key labour market outcomes. In this context it is important to understand not only the direct results of policy actions, but also the indirect effects, such as the effects of actions taken by firms and workers in response to policy measures. It is the aim of this Paper to provide such analysis. The Paper does so both qualitatively – discussing the mechanisms that operate when a policy measure is implemented, and quantitatively – showing how a particular policy generates a particular outcome, such as a change in unemployment. The Paper discusses prevalent policy tools: subsidies or taxes on hiring, subsidies or taxes on employment, payroll taxes and unemployment benefits. In addition the Paper looks at the result of changes in the real rate of interest and in productivity growth, and which macroeconomic variables are affected, among other things, by policy.

The framework used for this analysis is the search and matching model. This model emphasizes realistic aspects of labour markets not catered for by older models. In particular it assigns a key role to the time-consuming and costly search process which firms and workers undertake in order to find each other. A major role is also played by firm–worker bargaining that determines both wages and firms' profits from the job–worker match. The Paper simulates policy measures and their effects using data from the Israeli economy. This economy was chosen, because the institutional structure of its labour market generated data of unique quality for the purpose of this analysis.

The study finds that policy may be useful in overriding adverse effects of the search and matching process but that it may also generate negative effects of its own. Policy effects are analysed both in terms of levels (for example, by how much does unemployment decline for a given hiring subsidy), and in terms of business cycle fluctuations (for example, what are the changes in the persistence and the magnitude of fluctuations in the rate of unemployment when a given hiring subsidy is implemented). Effects on the persistence, co-movement and volatility of the major variables along the business cycle are discussed, demonstrating how policy affects rigidity in the labour market.

The key lessons emerging from the analysis are as follows:

(i) Hiring costs and unemployment benefits have substantial effects on labour market outcomes. Thus, provision of hiring subsidies or reduction in benefits have important consequences for the major variables. These results are consistent (though they do not constitute direct evidence or proof) with the view that high European unemployment is due to relatively high hiring costs and generous unemployment benefits.

(ii) Employment subsidies or payroll tax reductions are not very effective policy instruments as they ‘leak’ into increased wages. The share of the workers in the wage bargain is important for gauging the effectiveness of these policy measures.

(iii) Policy measures that reduce unemployment also reduce its persistence and increase the volatility of vacancies.

(iv) Policy might lead to high ‘equilibrium’ or ‘natural rate’ unemployment, relative to the case where there is no government intervention. The reason is that policy intervention affects wages and hence firms’ profits and vacancy creation. It is shown how unemployment may be reduced, even to non-intervention levels, mainly through the use of hiring subsidies and reduction of unemployment benefits.

An alternative interpretation of the analysis is that it provides a tool to assess the effects of varying the amount of frictions. Thus, it bears some possible implications for US–European unemployment differences. One such finding regards economies with laws and bureaucratic procedures that make hiring effectively more costly – such as some of the European countries. These economies, compared to those without such laws and procedures, should expect a higher rate of unemployment with longer duration and more persistence, and with all key variables less volatile and less cyclical.

Macroeconomic Policy Lessons of Labor Market Frictions

1 Introduction

In recent years the importance of the role of labor market frictions in aggregate fluctuations is increasingly recognized.[1] Much attention has also been given to movements of the 'natural rate of unemployment,' a concept which is closely linked to the existence of frictions. It has been argued that government policy may have an effect on this equilibrium rate; for example, several authors have claimed that the existence of certain policies explain, at least partially, high unemployment in Europe.[2] This paper explores the consequences of macroeconomic policy for equilibrium unemployment and other labor market outcomes, asking how policy interacts with frictions to affect key outcomes in both the long-run and over the course of the business cycle. It models labor market frictions as associated with search costs and job-worker matching processes. The analysis shows how policy may be useful in overriding frictions and how policy might generate adverse outcomes. It looks at the main tools of macroeconomic policy and pertains to both the non-stochastic steady state and to business cycle dynamics. The idea is to give both qualitative answers − identify the mechanisms that are in operation when a policy measure is introduced − and quantitative answers − by how much does a given policy measure change labor market outcomes, as well as the cost-effectiveness of each measure.

Such analysis faces several obstacles: (i) in order to quantify the effects of policy, the magnitude of frictions needs to be known and not simply *assumed;* (ii) other parts of the macroeconomy affect the labor market and any misspecification of these parts may bias the evaluation of policy effects on the labor market; (iii) misspecification is also an issue when specifying the stochastic, driving shocks. We rely on structural econometric estimates of the relevant parameters expressing

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[1] See the discussion in the recent surveys by Hall (1999) and by Mortensen and Pissarides (1999a) and references therein.

[2] See, for example, Krugman (1994) and the papers collected in Snower and de la Dehesa (1997).

the frictions to deal with point (i) and on VAR estimates using actual data to specify the stochastic behavior of the relevant exogenous variables to deal with points (ii) and (iii). This allows us to formulate an *empirically-grounded* model in stochastic, discrete-time terms. We then solve for the non-stochastic steady state analytically and for equilibrium dynamics (the dynamic path and business cycle fluctuations) numerically.

The model underlying this analysis postulates that employment grows through costly vacancy creation by firms and a matching process that pairs job vacancies to unemployed workers. Once the job-worker match is formed, bargaining determines wages. The firms optimize intertemporally, taking into account hiring costs, a given matching process and wage bargaining. Both the firm and the worker capture rents from the match. The workers' rents are the wages. The present value of the firm's rents − discounted by both the interest rate and the match-destruction rate − is part of the firm's value to its owners. The main ways that policy affects labor market outcomes are by enhancing firms' rents from job-worker matches or by cutting hiring costs. The former happens through either lower wage payments or increased revenues. These enhance vacancy creation. The consequence is that vacancies replace some of the unemployed workers in the "production" of matches. Hence the rate of unemployment falls and its duration declines.

To place the paper in the proper context in the literature[3] and highlight its contributions, several novel features of the analysis should be noted: First, using a partial equilibrium framework, it relies on reduced-form VAR of the actual data to specify the effect of exogenous variables. This "agnostic" approach precludes the possibility that labor market results will be affected by misspecifications in other parts of a more general macroeconomic model and at the same time lets the data determine the stochastic behavior of the exogenous variables. Second, the model is empirically-based and is shown to capture the main features of the data. The policy simulations rely on structural econometric estimates of the parameters that quantify the frictions. Third, the data-set used − Israeli labor market data − is particularly well-suited to studying labor market

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[3] See in particular the contributions of Pissarides (1998, 2000 chapter 9), Millard and Mortensen (1997) and Mortensen and Pissarides (1999b).

frictions. Fourth, the analysis is comprehensive in that it is both qualitative and quantitative, pertains to the non-stochastic and to stochastic, business-cycle aspects of the data, and examines a large set of macroeconomic policy measures – hiring subsidies, employment subsidies, payroll taxes, unemployment benefits and benefit taxes. Additionally, it considers the effects of key macroeconomic variables – the real rate of interest and the rate of productivity growth. The policy measures examined are comparable in terms of government expenditures and thus the results are used to evaluate policy effectiveness. The analysis shows how budget constraints may be used to solve for the value of policy instruments given firms' optimization and the structure of the market. Fifth, the model's formulation of firm's search costs as convex (rather than linear) in vacancy and hiring rates turns out to be important for the understanding of policy effects on the persistence and volatility of the key variables.

An alternative interpretation of the analysis is that it provides a tool to assess the effects of varying the amount of frictions. Thus, it bears some possible implications for U.S.–European unemployment differences. One such finding regards economies with laws and bureaucratic procedures that make hiring effectively more costly – such as some of the European countries. These economies, compared to those without such laws and procedures, should expect a higher rate of unemployment with longer duration and more persistence, and with all key variables less volatile and less cyclical.

We proceed as follows: Section 2 presents the model of the aggregate labor market with frictions, relegating technical derivations to appendices. Section 3 studies the mechanisms in operation when policy measures affect labor market outcomes. Section 4 discusses the Israeli labor market and the data. Section 5 presents a quantitative analysis of the model, sets a baseline and shows how it fits the data. Section 6 is the key quantitative section, reporting the effects of the policy measures, including discussion of policy effectiveness, the case of no intervention and the implications of budget constraints. Section 7 concludes.

2 The Model

In this section we present the model of the aggregate labor market with frictions. By frictions we refer to search costs and time-consuming matching. We basically build upon the Diamond-Mortensen-Pissarides model,[4] casting the analysis in stochastic, discrete-time terms. We describe the set-up (2.1), and then formalize the matching process (2.2), optimal search by firms (2.3), wage-setting (2.4), and solve for the non-stochastic steady state (2.5). We formulate an "agnostic," data-based approach to other parts of the macroeconomy, which are introduced into the model as stochastic, exogenous variables (2.6). We then formulate the dynamic system (2.7). We end the section by giving a graphical representation of the model (2.8).

2.1 The Set-Up

There are two types of agents: unemployed workers searching for jobs and firms recruiting workers through vacancy creation. Firms maximize their intertemporal profit functions with the choice variable being the number of vacancies to open. The firm's maximization problem is essentially a problem of investment under uncertainty. Workers are not fired at the end of every period and hired at the beginning of each period as in the neo-classical model. Rather employment evolves in a way similar to the evolution of the capital stock. In the same way as capital is accumulated through gross investment, workers are "accumulated" through the filling of vacancies; as capital depreciates, workers separate from jobs. Workers and firms are faced with frictions such as different locations leading to regional mismatch or lags and asymmetries in the transmission of information. These frictions are embedded in the concept of a matching function which produces hires out of vacancies and unemployment, leaving certain jobs unfilled and certain workers unemployed. Workers are

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[4] Key contributions were made by Diamond (1982a,b), Mortensen (1982) and Pissarides (1985). For empirical implications see Blanchard and Diamond (1989,1990). For recent surveys see Mortensen and Pissarides (1999a) and Pissarides (2000).

assumed to be separated from jobs at some exogenous rate.[5] The set-up, whereby search is costly and matching is time-consuming, essentially describes the market as one with trade frictions where supply and demand are not equilibrated instantaneously.

The model assumes a market populated by many identical workers and firms. Hence we shall continue the discussion in terms of "representative agents." Each agent is small enough so that the behavior of other agents is taken as given. As is well known, this creates various externalities. In particular, more search activity creates a positive trading externality for the trading partner and a congestion externality for similar agents [see the discussion in Diamond (1982a) and Pissarides (2000, chapter 7)].

We consider five kinds of policy measures: hiring subsidies and employment subsidies paid to firms, payroll taxes paid by workers, and unemployment income policy, including unemployment benefits and taxes paid on these benefits.

2.2 Matching

A matching function captures the frictions in the matching process; it satisfies the following properties:

$$\begin{aligned} M_{t,t+1} &= \widetilde{M}(U_t, V_t) \qquad (1) \\ \frac{\partial \widetilde{M}}{\partial U} &> 0, \ \frac{\partial \widetilde{M}}{\partial V} > 0, \ M_{t,t+1} \leq \min(U_t, V_t) \end{aligned}$$

where U is the stock of unemployed workers, V is the stock of vacancies and M is the flow of hires from unemployment to employment. Empirical work [previous work on Israeli data [Yashiv (2000a)], as well as work on other economies surveyed by Petrongolo and Pissarides (2000)] has shown that a Cobb-Douglas function with constant returns to scale is useful for parameterizing the matching function, i.e.:

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[5] The assumption of a constant match separation rate δ is a good approximation in the Israeli economy. The separation rate series has no trend and is stationary around its average value (4 percent a quarter).

$$M_{t,t+1} = \mu U_t^{\sigma} V_t^{1-\sigma} \tag{2}$$

where μ stands for matching technology.

2.3 The Firms' Dynamic Optimization Problem

Firms maximize (where all other factors of production have been "maximized out"):

$$\max_{\{V\}} E_0 \sum_{t=0}^{\infty} (\prod_{j=0}^{t} \beta_j) \left[(F_t - W_t N_t + \tau_N F_t - \Gamma_t) \right] \tag{3}$$

where $\beta_j = \frac{1}{1+r_j}$ and r is the rate of interest, F is output, W is the real wage, N is the employment stock and Γ denotes hiring costs. The employment subsidy is postulated as $\left(\tau_N \frac{F_t}{N_t}\right) N_t = \tau_N F_t$ with $0 \leq \tau_N < 1$.[6]

This maximization is done subject to the employment dynamics equation given by:

$$N_{t+1} = N_t(1-\delta) + Q_{t,t+1} V_t \tag{4}$$

where δ is the separation rate and $Q_{t,t+1} = \frac{M_{t,t+1}}{V_t}$.

The F.O.C are (where Λ is the discounted Lagrange multiplier):

$$\frac{\partial \Gamma_t}{\partial V_t} = Q_{t,t+1} E_t \Lambda_t \tag{5}$$

$$\Lambda_t = E_t \beta_{t+1} \left[\frac{\partial F_{t+1}}{\partial N_{t+1}} (1+\tau_N) - W_{t+1} - \frac{\partial \Gamma_{t+1}}{\partial N_{t+1}} \right] + E_t (1-\delta) \beta_{t+1} \Lambda_{t+1} \tag{6}$$

as well as equation (4) and the transversality condition:

$$\lim_{T\to\infty} E_t \left[(\prod_{j=0}^{T-1} \beta_j) \left\{ \frac{\partial F_T}{\partial N_T}(1+\tau_N) - W_T - \frac{\frac{\partial \Gamma_{T-1}}{\partial N_{T-1}}}{\beta_{T-1}} \right\} N_T \right] = 0 \tag{7}$$

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[6] This formulation makes total subsidy payments increase at the rate of growth of the economy.

The first, intratemporal condition (equation 5) sets the marginal cost of hiring $\frac{\partial \Gamma_t}{\partial V_t}$ equal to the expected value of the multiplier times the probability of filling the vacancy. The second, intertemporal condition (equation 6) sets the multiplier equal to the sum of the expected, discounted marginal profit or dividend in the next period $E_t \beta_{t+1} \left[\frac{\partial F_{t+1}}{\partial N_{t+1}} (1 + \tau_N) - W_{t+1} - \frac{\partial \Gamma_{t+1}}{\partial N_{t+1}} \right]$ and the expected, discounted (using also δ) value of the multiplier in the next period $E_t(1-\delta)\beta_{t+1}\Lambda_{t+1}$.

The value of the multiplier has the following economic interpretation: it reflects the expected present value of the match from the point of view of the firm, or in other words "the asset value" of the match. Note that both the firm and the worker capture rents from the match. The workers' rents are the wages, discussed in the next sub-section. In what follows we shall discuss how policy affects these rents.

We parameterize F and Γ as follows. For production we assume a standard Cobb-Douglas function:

$$F_t = A_t {N_t}^{\alpha} K_t^{1-\alpha} \tag{8}$$

where A is technology and K is capital.

Hiring costs refer to the costs incurred in all stages of recruiting: the cost of advertising, screening, training, and the cost of disrupting production. Relying on the empirical results in Yashiv (2000b), who tested alternative functional forms and variables to be included, we use the following formulation:

$$\Gamma_t = \frac{\Theta(1-\tau_\Theta)}{1+\gamma} (\psi \frac{V_t}{N_t} + (1-\psi)\frac{M_t}{N_t})^{1+\gamma} F_t, \qquad 0 \leq \tau_\Theta < 1 \tag{9}$$

where we have postulated a hiring subsidy τ_Θ; Θ is a scale parameter while $1+\gamma$ expresses the degree of convexity. Hiring costs are internal to production and hence are proportional to output (F). They are increasing in a weighted average of the vacancy ($\frac{V_t}{N_t}$) and hiring ($\frac{M_t}{N_t}$) rates as part of the costs relates to vacancies, even if unfilled, and part to actual hires. The function is linearly homogenous in V, M, N and F. It encompasses the cases of a fixed cost per vacancy and of increasing costs. When $\gamma = 1$ (and there are no subsidies) we get the quadratic formulation $(\frac{\Theta}{2}(\psi\frac{V_t}{N_t} + (1-\psi)\frac{M_t}{N_t})^2 F_t)$ which is analogous to the standard formulation in "Tobin's q" models of investment where costs are quadratic in $\frac{I}{K}$.

2.4 The Wage Solution

The wage is determined by the Nash solution to the following bargaining problem:

$$W_t = \arg\max(J_t^N - J_t^U)^{\xi}(J_t^F - J_t^V)^{1-\xi} \tag{10}$$

where J^N and J^U are the present value for the worker of employment and unemployment respectively; J^F and J^V are the firm's present value of dividends from a filled job and from a vacancy respectively; and $0 < \xi < 1$ reflects the degree of asymmetry in bargaining.

We assume that the value of unemployment, to be denoted b, includes two components: non-pecuniary income and unemployment benefits. Relying on the empirical results in Yashiv (2000b), we further assume that this value can be represented by the following function:

$$b_t = z\frac{F_t}{N_t} + \rho(1 - \tau_b\tau_W)W_t \tag{11}$$

The first term captures non-pecuniary income and assumed proportional to average (or marginal) output with a parameter z. The second term captures unemployment benefits with the gross replacement ratio denoted ρ; benefits are taxed at a rate $\tau_b\tau_W$, with $0 \leq \tau_b \leq 1$. Policy thus has two tools $-$ ρ and τ_b- to affect b.[7]

The wage solution is given by (see Appendix A for the full derivation):

$$W_t = \eta\left(\frac{\partial F_t}{\partial N_t}(1 + \tau_N) - \frac{\partial \Gamma_t}{\partial N_t} + E_t P_{t,t+1}\Lambda_t\right) + \omega z \frac{F_t}{N_t} \tag{12}$$

where:

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[7] While ρ and τ_b both affect the net replacement ratio their quantitative effect, examined below, is not quite the same.

$$\eta \equiv \frac{\xi(1-\tau_W)}{(1-\tau_W)-(1-\xi)\rho(1-\tau_b\tau_W)} \tag{13}$$

$$\omega \equiv \frac{(1-\xi)}{[(1-\tau_W)-(1-\xi)\rho(1-\tau_b\tau_W)]} \tag{14}$$

Wages depend on three terms: current productivity $(\frac{\partial F_t}{\partial N_t}(1+\tau_N)-\frac{\partial \Gamma_t}{\partial N_t})$, the product of the worker's hazard rate and the future value of the match $(E_t P_{t,t+1}\Lambda_t)$ and non-pecuniary income $(z\frac{F_t}{N_t})$.

Workers pay a payroll tax at rate $0 \leq \tau_W \leq 1$. In this equilibrium set up, the analysis would not change if these taxes were levied on firms. Note that in the present set-up W is the gross wage.

As 'market tightness' $\frac{v}{u}$ rises, the worker's hazard rate P rises and generates a wage increase. Note that an employment subsidy τ_N increases the surplus and a proportion η of it accrues to workers. The payroll tax τ_W, the benefits tax $\tau_b\tau_W$, and the gross replacement ratio ρ do not affect the surplus itself but change the labor share of it, as shown by the following derivatives:

$$\begin{aligned}\frac{\partial W_t}{\partial \tau_W} &= \frac{\partial \eta}{\partial \tau_W}\left(\frac{\partial F_t}{\partial N_t}(1+\tau_N)-\frac{\partial \Gamma_t}{\partial N_t}+E_t P_{t,t+1}\Lambda_t,\right) \\ &\quad + \frac{(1-\xi)(1-(1-\xi)\rho\tau_b)}{[(1-\tau_W)-(1-\xi)\rho(1-\tau_b\tau_W)]^2} z\frac{F_t}{N_t}\end{aligned} \tag{15}$$

$$\begin{aligned}\frac{\partial W_t}{\partial \tau_b} &= \frac{\partial \eta}{\partial \tau_b}\left(\frac{\partial F_t}{\partial N_t}(1+\tau_N)-\frac{\partial \Gamma_t}{\partial N_t}+E_t P_{t,t+1}\Lambda_t\right) \\ &\quad - \frac{(1-\xi)^2\rho\tau_W}{[(1-\tau_W)-(1-\xi)\rho(1-\tau_b\tau_W)]^2} z\frac{F_t}{N_t}\end{aligned} \tag{16}$$

$$\begin{aligned}\frac{\partial W_t}{\partial \rho} &= \frac{\partial \eta}{\partial \rho}\left(\frac{\partial F_t}{\partial N_t}(1+\tau_N)-\frac{\partial \Gamma_t}{\partial N_t}+E_t P_{t,t+1}\Lambda_t\right) \\ &\quad + \frac{(1-\xi)^2(1-\tau_b\tau_W)}{[(1-\tau_W)-(1-\xi)\rho(1-\tau_b\tau_W)]^2} z\frac{F_t}{N_t}\end{aligned} \tag{17}$$

The effects of changing unemployment benefits are straightforward: when unemployment compensation increases, the workers' threat point rises and with it the wage. As the replacement ratio (ρ) rises or as benefits are taxed less (τ_b falls), wages increase with the rise in the workers' threat point. Hence $\frac{\partial W}{\partial \rho}$ is positive and $\frac{\partial W}{\partial \tau_b}$ is negative.

The effect of the payroll tax τ_W is more complex. The second line of (15) is positively signed: as τ_W rises, the value of the part of the outside option which is not taxed rises (the weight on $z\frac{F_t}{N_t}$ rises) thereby leading to an increase in wages. The sign of the first line of (15) depends on the effect of the tax on the share η :

$$\frac{\partial \eta}{\partial \tau_W} = \frac{-\xi A + [\xi(1-\tau_W)\,(1-(1-\xi)\rho\tau_b)]}{A^2} \tag{18}$$

where $A = (1-\tau_W) - (1-\xi)\rho(1-\tau_b\tau_W)$.

This expression depends on the value of τ_b, i.e. on the degree of linkage between payroll taxes and benefits taxes. It is instructive to consider two extremes: if $\tau_b = 0$, benefits are not taxed at all. As payroll taxes rise the value of unemployment relative to employment rises, raising the threat point of the worker in the wage bargain. This operates to increase the worker share. Hence $\frac{\partial \eta}{\partial \tau_W}$ is positive. If $\tau_b = 1$, i.e. wages and benefits are taxed at the same rate, then there is no effect on the wage share i.e. $\frac{\partial \eta}{\partial \tau_W} = 0$.

Hence the overall effect of payroll taxes on wages is positive because the first line in (15) is positive or zero, as was just shown, and the second line is positive.

The implication is that policy can reduce wages by reducing the replacement ratio (ρ), by raising benefit taxes (τ_b), or by lowering payroll taxes (τ_W).

2.5 The Non-Stochastic Steady State

The non-stochastic steady state is characterized by two key relations. First, the rate of vacancy creation is given by:

$$\frac{\frac{\partial \Gamma}{\partial V}}{\frac{F}{N}} = Q\lambda = Q\frac{G^X\beta}{1-G^X\beta(1-\delta)}\pi \tag{19}$$

where G^X is the gross rate of productivity growth. This equation is set in terms of average output. The LHS are marginal costs; the RHS is the probability of filling a vacancy (Q) times the asset value of the match in the steady state ($\lambda = \frac{\Lambda}{F/N}$). This value is the product of per-period marginal dividends π and a discount factor $\frac{G^X\beta}{1-G^X\beta(1-\delta)}$ that takes into account the real rate of interest, the rate of separation and productivity growth.

With the specific functional forms chosen for the matching function (equation 1), the production function (equation 8) and the hiring cost function (equation 9), we get the following expressions for per-period match dividends (π) and the gross wage share (s) in the steady-state.

$$\pi = \frac{\left(\alpha(1+\tau_N) - \frac{\frac{\partial\Gamma}{\partial N}}{\frac{F}{N}}\right)(1-\eta)}{(1+\eta P\Phi)} - \frac{\omega}{(1+\eta P\Phi)}z \tag{20}$$

$$s = \frac{W}{\frac{F}{N}} = \eta\left(\left(\alpha(1+\tau_N) - \frac{\frac{\partial\Gamma}{\partial N}}{\frac{F}{N}}\right) + P\Phi\pi\right) + \omega z \tag{21}$$

where:

$$\Phi = \frac{G^X\beta}{1-G^X\beta(1-\delta)}$$

$$\frac{\partial\Gamma}{\partial N} = -\Theta(1-\tau_\Theta)\left(1-\frac{\alpha}{1+\gamma}\right)\left(\psi\frac{V}{N} + (1-\psi)\frac{M}{N}\right)^{1+\gamma}\frac{F}{N}$$

The second key steady-state relation relates to equilibrium labor market flows. These are derived from equating the rate of increase in employment with the rate of separation and increase in the labor force:

$$\delta + G^L - 1 = \frac{M}{N} = \mu\left(\frac{U}{N}\right)^{\sigma}\left(\frac{V}{N}\right)^{1-\sigma} \tag{22}$$

where G^L is the gross rate of labor force growth.

From this equation the rate of unemployment in equilibrium, the natural rate, is given by:

$$\frac{U}{L} = \frac{\delta + (G^L-1)}{\delta + (G^L-1) + P} \tag{23}$$

where:

$$L = N + U \tag{24}$$

Equations (19) and (22) shall be at the heart of the analysis.

2.6 The Exogenous Variables

The model has three exogenous variables that are determined in other markets. These are productivity growth (G^X), labor force growth (G^L), and the discount factor (β). It is these variables that inject shocks into the system. Intentionally, we do not formulate the underlying structural shocks. Instead, we postulate that these exogenous variables (in terms of log deviations from their non-stochastic steady state values) follow a first-order VAR. Using the notation $\widehat{Y}_t = \frac{Y_t - Y}{Y} \approx \ln Y_t - \ln Y$ for any variable Y_t, where Y is the steady-state value, this is given by:

$$\begin{bmatrix} \widehat{G}^X_{t+1} \\ \widehat{G}^L_{t+1} \\ \widehat{\beta}_{t+1} \end{bmatrix} = \Pi \begin{bmatrix} \widehat{G}^X_{t} \\ \widehat{G}^L_{t} \\ \widehat{\beta}_{t} \end{bmatrix} + \Sigma \tag{25}$$

In Section 5 below we use reduced-form VAR estimates of the *actual data* to quantify the coefficient matrix Π and the variance-covariance matrix of the disturbances Σ. Thus the current model takes an "agnostic approach," which is consistent with models that emphasize demand shocks as well as with models that emphasize technology shocks.

In what follows we cast all labor market variables in terms of rates out of the labor force (L) and divide all relevant variables by the average output ($\frac{F}{N}$). This leaves a system that is stationary and is affected by the afore-cited shocks.

2.7 The Dynamic System

Two aspects of the dynamics will be studied: (i) the dynamic path, when all exogenous variables are at their steady state level (i.e. non-stochastic dynamics) and (ii) stochastic steady-state dynamics, which capture business cycle fluctuations. To do so we need to solve the model numerically. This is done by log-linearizing the model around the steady state (see Appendix B).

The approximation of equations (4), (5), and (6) around the steady state yields the following first-order difference equation system, where all variables are in terms of log deviations from steady state:

$$\begin{bmatrix} \widehat{n}_{t+1} \\ \widehat{\lambda}_{t+1} \end{bmatrix} = B \begin{bmatrix} \widehat{n}_{t} \\ \widehat{\lambda}_{t} \end{bmatrix} + C \begin{bmatrix} \widehat{G}^X_{t+1} \\ \widehat{G}^L_{t+1} \\ \widehat{\beta}_{t+1} \end{bmatrix} \tag{26}$$

where B and C are matrices of coefficients, which are complicated functions of the system's parameters and steady state values.

The system is defined in terms of the endogenous state variable (the employment rate, $\widehat{n}_t$) and the co-state variable (the asset value of the match, $\widehat{\lambda}_t$) and the three exogenous variables (productivity growth, $\widehat{G}^X_{t+1}$, labor force growth $\widehat{G}^L_{t+1}$and the discount factor $\widehat{\beta}_{t+1}$). The other variables of interest – the firms' control variable ($\widehat{v}_t$, the vacancy rate) and the other endogenous state variables ($\widehat{u}_t, \widehat{P}_t, \widehat{Q}_t, \widehat{m}_t$) – are functions of the above variables. The solution of (26) allows for the derivation of the dynamic path and the stochastic dynamics, as explained in Appendix B. The properties of the system in terms of stability and dynamic paths are determined by the relevant eigenvalues. For plausible values of the parameters and steady state values – as discussed in Section 5 below – the system turns out to be a saddle, with a unique convergent path (see Appendix B for the formal condition).

2.8 Graphic Representation of Labor Market Equilibrium

Figure 1 represents the non-stochastic steady state of the model. Panel (a) illustrates the marginal hiring cost curve and the expected asset value curve. Their intersection is the graphical expression of the F.O.C. (equation 19). Thus vacancy creation is at the point where the upward-sloping marginal hiring costs curve ($\frac{\partial \Gamma}{\partial \frac{V}{\frac{F}{N}}}$) intersects the downward-sloping marginal match asset value curve

$(Q\frac{G^X\beta}{1-G^X\beta(1-\delta)}\pi)$. Panel (b) shows the equilibrium in $\frac{U}{N}-\frac{V}{N}$ space: the upward sloping curve represents optimal vacancy creation (i.e. equation (19)) and the downward-sloping curve represents the steady-state flow relationship (equation 22). The latter is often labeled 'the Beveridge curve.'

Figure 1

When studying the various policy measures and the resulting equilibria we relate them to the movements in these curves.

3 The Effects of Policy on Labor Market Equilibrium

Policy affects labor market outcomes either by changing firms' hiring costs or by changing the asset value of the match. In this section we study these effects qualitatively. In the following ones we examine the same policy schemes quantitatively. All five policy tools can cause a movement of the vacancy supply schedule along a given Beveridge curve, i.e. a movement between points like A and B in panel (b) of Figure 1. As a consequence, equilibrium unemployment and vacancy rates, hazard rates and duration are affected as well as firms' match values and workers' wages.

To see what mechanisms are in operation, consider a policy aimed at reducing unemployment. Such policy can bring the economy to a steady-state whereby for the same labor market flows (matching, separation and labor force growth) there is less unemployment. This is done by substituting unemployed workers for vacant jobs in the 'production' of matches, i.e. by moving upwards on the $\widehat{u}=0$ curve (the 'Beveridge curve'). Thus policy generates a substitution of inputs into the matching function.[8] This change in steady-state can take place if the government finances higher rates of vacancy creation, and if in the short-run vacancies increase sufficiently so as to

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[8] Policy could conceivably affect the position of the Beveridge curve itself were it to have an effect on the matching technology (μ) or on the separation rate (δ).

generate this substitution. With these changes, other variables are affected: with the afore-cited substitution $\frac{v}{u}$ rises and so the hazard rate (P) rises and unemployment duration falls; wages are affected as the surplus of the job-worker match changes and/or the worker's bargaining power is affected. The latter happens because government policy may change the value of the 'threat point' or reservation wage of the worker (the value of unemployment) relative to employment. As to firms, there are effects on the asset value of the job-worker match. The latter effects complement those described for wages.

Specifically, hiring subsidies give the firm $0 \leq \tau_\Theta \leq 1$ of every unit of output spent on hiring costs. The essential effect of the subsidy is to make the marginal hiring curve flatter. This is akin to the labor demand curve becoming flatter. In panel (a) of Figure 1 this is depicted by the movement from A to B. The subsidy has several effects: it lowers vacancy creation costs for firms thereby leading to more creation. Higher vacancy rates lead to lower unemployment and generate the well-known search externalities $-$ the hazard rate for firms (Q) declines and that for workers (P) increases. The rise in P increases workers' wages and hence erodes firms' match dividends. The asset value of the match declines because there is a decline both in the probability of filling a vacancy (Q) and in per-period match dividends (π).

Employment subsidies give the firm $\tau_N \frac{F_t}{N_t}$ for every worker, with $0 \leq \tau_N \leq 1$. The essential effect of the subsidy is to increase match dividends. In Figure 1 this is shown as the movement from A to C in Panel (a) and from A to B in panel (b). By increasing match dividends the subsidy leads to more vacancy creation. Higher vacancy rates lead to lower unemployment and generate the same search externalities discussed above (the hazard rate for firms declines and that for workers increases). Wages rise as both the subsidy τ_N and the hazard rate P rise. The increase in per-period dividends and asset values is mitigated by the rise in wages.

The essential mechanism with respect to the payroll tax is that it affects the worker share in the wage bargain (η), as discussed above (see the discussion following equation (12)). Lowering the payroll tax lowers the wage share and increases firms' match dividends. In Figure 1, this can be seen again in the movement from A to C in Panel (a) and from A to B in panel (b). Lowering the replacement ratio (ρ) or raising the benefit tax rate (τ_b) operates in a similar way to lowering the payroll tax.

We also consider changes in the determinants of the discount factor, as some policy measures may influence these variables too. The discount factor is given by:

$$\Phi = \frac{G^X \beta}{1 - G^X \beta (1 - \delta)} \tag{27}$$

Increases in productivity growth increase the discount factor while increases in the real rate of interest or in the separation rate have the opposite effect. The expected asset value of the match is given by $Q\Phi\pi$. It depends on the discount factor both directly − a positive relationship − and through per-period match dividends π. To see the effects of the discount factor on the latter consider equations (20) and (21). The surplus from the match includes an expression for the asset value of the match (given by λ). Wages constitute a share of this surplus and are thus positively dependent on the discount factor. When the discount factor falls (rises), wages decrease (rise). Hence per-period marginal match dividends (π), which decline in wages, rise (fall). Thus when the discount factor changes there are contradictory effects on the expected present value of the match. In the numerical analysis below, the former effect is shown to be dominant. Hence once more there is a movement from A to C in panel (a) of Figure 1 and from A to B in panel (b).

As mentioned, the quantitative analysis indicates that the transition from one steady state to another occurs along a unique, convergent (saddle) path. We depict these paths in the numerical analysis below.

4 The Labor Market and the Data

We use Israeli data and structural estimates of the key relations to set a baseline model for quantitative analysis. The reason for looking at Israel is that its data are particularly well-suited to study labor market frictions, with time series that match the model's definitions of the relevant variables. Additionally, Yashiv (2000 a,b) estimated the model and found support for it in these data. These estimates are used below in the simulation analysis.

In order to appreciate the quality of the data, a short description of the institutional set-up of the market is called for. The Israeli labor market is essentially composed of two main segments: the market for jobs that do not require a university degree and the market for jobs that require academic qualifications. Matching of workers and jobs in the former segment was done for many years by the main institutional intermediary in the Israeli labor market, the Employment Service (ES) which is affiliated to the Ministry of Labor. From 1959 until March 1991 private intermediaries were illegal and hiring of workers for these jobs *was required by law* to pass through the ES. On the other side of the market, unemployed workers must register with the ES in order to qualify for unemployment benefits. Firms post vacancies in quite specific terms: they are required to fill out a detailed form when registering vacancies including their exact number and the type of job required, and have to renew them at the beginning of each month. This procedure renders vacancies a concrete meaning and places them on equal footing with the unemployment figures. The latter are the result of workers' appearances at the ES bureau where they too filled out a detailed form. Therefore ES data give comprehensive coverage and offer the opportunity to study unemployment, vacancies and matches that are well defined. There are several indications with respect to the relative size of the ES sector: the share of university graduates among employed workers was 35 percent at the end of the sample period (1975-1989) and lower than that – at around 20-25 percent – in the course of the period. The ratio of ES unemployment to unemployment according to the Labor Force Survey (LFS) was about 60 percent on average in the years 1962 (when ES measurement began) till 1990 (the end of vacancy data availability). Therefore a lower bound on the share of the ES segment is 60 percent of the market and it would not be unreasonable to estimate its actual share in the sample period as 70-80 percent.

Figure 2 reports the rate of unemployment taken from the Labor Force Survey (LFS) of the Central Bureau of Statistics (CBS).[9] Figure 3 plots Employment Service data on job vacancies

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[9] Beginning in the first quarter of 1995 LFS definitions were changed to conform with ILO guidelines. Thus this series (as well as others) is not directly comparable before and after that date.

and hiring, as rates out of the labor force in the period 1975-1989.[10]

Figures 2 and 3

Following a rise in 1980 unemployment never regained its levels of the previous decades: in the period 1960-1979 the average rate was 4.2%. In the following period (1980-1995) it averaged 7.2%. Other LFS data (not shown) indicate that concurrently with this rise, the duration of unemployment increased too. There was a substantial decline in vacancy and hiring rates going from the 1970s to the 1980s; the rate of vacancies also drew closer to the rate of matching, implying that the duration of vacancies fell going from the 1970s to the 1980s.

5 Baseline Model and Data Fit

In this section we derive the baseline model to be simulated for policy effects. We give values to the parameters (5.1) and evaluate the data fit of this baseline model (5.2).

5.1 Baseline Model

For the *parameters* we use the estimates reported in Yashiv (2000 a,b) to give numerical values to the parameters γ and ψ of the hiring cost function, the labor parameter in the production function (α), the worker's bargaining parameter (ξ) and the unemployment elasticity σ of the matching function. The scale parameters of the hiring cost function (Θ) and of the matching function (μ) are set so that the solution of the system will yield the steady state values of $\frac{U}{N}$ and $\frac{V}{N}$ discussed below.

For the *variables* in steady state we take data averages[11]or solve them out of the steady state relations. For $\frac{U}{L}$ we take the average unemployment rate (in LFS data) from 1980 till 1995.

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[10] Vacancy definitions were changed in 1975 so the preceding period is not reported. The data end in 1989 because the series are no longer comprehensive once private intermediaries were allowed.

[11] Appendix C gives full definitions and sources of the data.

We use this period because as seen in Figure 2 above, the post-1980s period was markedly different than the preceding period and in 1995 LFS definitions were changed. From this rate (7.2%) of $\frac{U}{L}$ we deduce the rate $\frac{U}{N}$ at 7.8%. We take LFS data on unemployment duration, with an average of approximately 20 weeks, and set $P = 0.60$. The analog hazard rate for firms is available from ES data on vacancies and is set to be $Q = 0.8$. We use the steady state relationship $\frac{P}{Q} = \frac{V}{U}$ and the values of $\frac{U}{N}, P$ and Q to set $\frac{V}{N}$ at 5.8% per quarter. As a further check on the validity of the latter figure note that the average of $\frac{V}{N}$ in the data is 6%. This allows us to derive $\frac{M}{N} = Q\frac{V}{N}$ at 4.7% per quarter. Labor force growth – excluding government employment – was 0.6% per quarter in the pre-1990s period, before immigration temporarily raised this number. We thus take $G^L = 1.006$. This allows us to derive the rate of separation $\delta = \frac{M}{N} - (G^L - 1)$ at 4.1%. For the gross rate of business sector labor productivity growth G^X we use NIPA and LFS data in the period 1980-1995 and get 1.005. For the real rate of interest r there are discrepancies between different data series: use of the rate of growth of non-durable consumption (the series normally used in general equilibrium models) yields an average of 0.8% per quarter in the period post-1980. Use of the most reliable market interest rate series – the rate charged by commercial banks on loans deflated by GDP deflator inflation – yields an average of 1.3% per quarter. In studies of the U.S. economy a rate of 1% per quarter is a prevalent value. We take the latter value as it is also a reasonable approximation of the average of the two series mentioned.

Based on the data, in the baseline we postulate no hiring or employment subsidies ($\tau_\Theta = \tau_N = 0$), payroll taxes (τ_W) at 28%, and the replacement ratio (ρ) at 0.4.[12] The values of π, s, z and $Q\Phi\pi$ are then solved out from (19), (20) and (21).

We use the methodology described above in Section 2.6 and in Appendix B below to derive the moments of the dynamic system.

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[12] The former value is based on Table 6.10 in the CBS Annual Bulletin of Statistics, reporting household direct taxes and social security payments as a fraction of national income. For the latter we use National Insurance Agency and CBS data to divide the monthly average of nominal unemployment benefits per person by the average nominal wage for employee post in the business sector.

Panels (a)-(d) of Table 1 report the baseline values, all in quarterly terms.

Table 1

Note the relation between the graphs of Figure 1 and the values reported in Table 1: the expression $Q\Phi\pi$ denotes the equilibrium value of marginal costs and marginal benefits in panel (a) of the figure. The values of $\frac{v}{n}$ and $\frac{u}{n}$ are the equilibrium values in panel (b). The slope of a ray from the origin passing through this equilibrium gives the ratio $\frac{v}{u}$ which determines P and Q. Given the exogenous Φ, the value of per-period match dividends π can then be deduced from $Q\Phi\pi$. Panel (d) shows statistics related to the saddle path. This path in the case of employment (in log deviations from steady state) is given by (see Appendix B):

$$\widehat{n}_{t+1} = \nu_1 \widehat{n}_t \tag{28}$$

The panel reports both ν_1 and the half-life statistic, i.e. the number of quarters in which half the percentage deviation from steady state is eliminated.

5.2 The Fit of the Baseline Model

How do the key variables behave stochastically? In particular what are their business cycle features? Panel (f) of Table 1 documents the co-movement, volatility and persistence in the data and as implied by the baseline model. The following sums up the features of the data and the performance of the model:

(i) The rate of employment (and unemployment) is highly persistent as evidenced by the auto-correlation $\rho(\widehat{n}_t, \widehat{n}_{t-1})$ of 0.95; the model captures it well.

(ii) There is a negative correlation between unemployment and vacancies $\rho(\widehat{u}_t, \widehat{v}_t)$. This is the so-called “Beveridge curve.” This moment too is captured by the model.

(iii) There is virtually zero correlation between the rate of employment and the rate of productivity growth ($\rho(\widehat{n}_t, \widehat{G}_t^X)$). This is an issue that has attracted much attention in the business cycle literature and is very well captured by the model.

The next two features are captured by the model but quantitatively not as well:

(iv) Vacancies are much more volatile than employment ($\frac{\text{std}\,\widehat{v}}{\text{std}\,\widehat{n}}$ is high). Noting that vacancies in this model are akin to investment in labor, this point is reminiscent of the business cycle fact that investment in capital is highly volatile. The model generates volatile vacancies but not as volatile as the data indicate.

(v) The labor share (s) is moderately pro-cyclical and more volatile than employment; the model's moments have the same signs but overstate their magnitude.

6 Quantitative Policy Effects

In this section we simulate the effects of policy. First, we look at how comparable policy measures affect all key variables in the steady-state, along the dynamic (saddle) path and in terms of business cycle dynamics (6.1). We then study saddle path dynamics (6.2). Subsequently we evaluate policy effectiveness, comparing the different measures (6.3). Next, we look at the case of no policy intervention (6.4). Finally, we consider policy determination with budget constraints (6.5).

6.1 Effects on Labor Market Outcomes

Table 2 quantifies the effects of the policy moves discussed in Section 3, by looking at changes in the policy parameters relative to the baseline. In all cases policy parameters are permanently changed. In order to facilitate comparison between these measures we look at policy schemes that cost or generate revenues equal to 1% of output.[13] There are five panels for the different policy schemes

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[13] Throughout this analysis we use the baseline values of the parameters and exogenous variables, except for the policy parameter under study. We re-derive the moments of the dynamic system approximated around each steady state.

and for the effects of the discount rate, each sub-divided into three sections. The first section reports the steady state values of all key variables. The second section reports the non-stochastic dynamic path (the saddle path) – both the auto-correlation parameter ν_1 and the half-life statistic. The third section reports business cycle statistics, i.e. the co-movement, persistence and volatility statistics of the key variables. In each case, the value of the policy variable in question is reported in the top row. Each panel also reports the baseline case.

Table 2 - I

Panel I shows the effects of a hiring subsidy that costs 1% of output ($\tau_\Theta = 42.92\%$) and of a hiring tax ($\tau_\Theta = -72.16\%$), which generates revenues equal to 1% of output. Section (a) shows the effects on the non-stochastic steady state. Several results stand out: subsidy and tax of equal value generate asymmetric effects in absolute value due to the curvature of the hiring cost curve and of the Beveridge curve. These policy schemes generate significant changes in equilibrium unemployment, i.e. in the natural rate, with the subsidy bringing it down to a 'U.S.-type' level of 5.4% and the tax up to a 'European-type' level of 9.7%. This result indicates that the frictions embodied in the hiring and training process are of substantial importance for steady-state unemployment. Subsidizing the firm with almost half of the cost spent on every hire has several sizable effects: unemployment drops 1.8 percentage points and its duration declines from an average of about 21 weeks to 16 (as the hazard rate, P, rises). Additionally the gross wage (as a fraction of income) rises by 0.25 percentage points. On the firms' side vacancy creation rises but both the hazard rate (Q) and per-period match dividends (π) decline and so the expected asset value of the match ($Q\Phi\pi$) declines to about 65% of its initial value. Section (b) shows that the subsidy policy makes the employment rate – and consequently unemployment – less persistent along the saddle path and thus half of a given percentage deviation from steady state is eliminated after 3.1 quarters, as compared with 4.4 quarters in the baseline case. This is so because under the subsidy policy the vacancy rate responds more to changes in the expected value of the match, as the marginal cost curve in panel

(a) of Figure 1 becomes flatter. Moving to section (c) we see the same phenomenon in stochastic terms: with a flatter curve, asset values λ and consequently vacancies become even more volatile. It follows that vacancies react more to shocks and so employment and unemployment persistence declines. The negative $U-V$ relationship strengthens with this increased sensitivity. As these changes in λ take place, the wage share (s) which depends on it, becomes more pro-cyclical and more volatile. Note that a tax on hiring generates the opposite effects: vacancy creation becomes more "rigid" and so volatility declines and persistence increases. One implication of these results is that European countries, with laws and bureaucratic procedures that make hiring effectively more costly, should expect not only higher unemployment with longer duration, but also all key variables to be less volatile, more persistent, and less cyclical relative to an economy without these factors.

Panel II shows the effects of a 1% employment subsidy ($\tau_N = 1\%$) and a 1% employment tax ($\tau_N = -1\%$).

Table 2 - II

The subsidy policy has qualitative effects which are similar to hiring subsidies, as discussed in Section 3. However, a 1% subsidy, while equal in terms of government outlays to the hiring subsidy discussed above, has small quantitative effects on all dimensions. The notable exception is the rise in the wage share (s) which is bigger than in the hiring subsidies case. The reason is that the employment subsidy increases the surplus of the match and workers get part of this increase in the wage bargain. Wages rise also because of the increase in the workers' hazard rate (P). Match dividends do rise, as the positive subsidy effect dominates the negative effect of the rise in wages, but the resulting increase is relatively small. Hence vacancy creation increases only slightly. The leak into wages is thus of crucial importance for the effectiveness of the subsidy. This leak depends on the wage bargaining parameter ξ. We report the effects on the key variables when varying this parameter, following the variation across estimation specifications reported in Yashiv (2000b). We look at the two extremal points of this range: $\xi = 0.1$ and $\xi = 0.3$.[14] The conclusion is that the higher is ξ, the smaller is the effect of the subsidy, due to bigger leakage into wages. However, in any case, the effect is relatively small.

Panel III examines the effects of changing the payroll tax (τ_W).

Table 2 - III

Like the employment subsidy case, a payroll tax decline or increase equal to 1% of output has a small effect on labor market outcomes. A tax reduction operates to decrease wages, enhance match dividends and hence vacancy creation, leading to lower unemployment. The decrease in taxation generates a decrease in unemployment persistence and a rise in the volatility of vacancies. Here too the value of ξ matters. The lower the wage bargaining parameter, the more effective is this policy scheme. Once more the effects are small, relative to the hiring subsidies case, irrespective of the value of ξ.

Panel IV looks at unemployment benefits (ρ) and at their taxes (τ_b).

Table 2 - IV

These are policy measures which affect the wage. In order to reduce unemployment, the government needs to *lower* unemployment benefits, which involves a reduction in expenditures. The differences examined are equal in value to 1% of output. A decrease in ρ generates a reduction in wages as benefits determine the workers' threat point in the wage bargain. Hence there is an increase in match dividends and in the asset value of the match. Vacancy creation is enhanced, unemployment falls and its duration declines. Declining unemployment benefits lower the

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[14] Note that in the dynamic analysis (sections b and c in the table) the baseline itself changes to reflect the modified value of ξ.

persistence of employment and increase the volatility of vacancies. These results too may explain U.S.−European unemployment differences, as European economies have much higher replacement ratios [see for example Chart 8.1 and Table 8.1 in OECD (1994, pp.174-175)]. In fact these differences are in the order of magnitude of the differences in ρ (17% vs. 53%) and unemployment rates (about 6% vs. 9%) reported here. Reducing benefit taxes (τ_b) is qualitatively equivalent to raising ρ. In this case we are unable to compute a tax reduction of 1% of output as the initial tax receipts are lower than that, so we simply compute $\tau_b = 0$ and compare it to the baseline of $\tau_b = 1$. The numbers indicate that this is an effective policy tool. Varying benefit tax rates between 0 and 100% varies the rate of unemployment over 2 percentage points (between 9.3% and 7.2%) and the asset value of the match between 150% and 165%. Business cycle properties too are affected. Note that lowering τ_b to zero costs less than 1% of output in diminished revenues but causes a bigger rise in unemployment than an increase in benefit payments of 1% of output.

Panel V looks at the effects of a change in the discount factor Φ.

Table 2 - V

The latter is a function of the real rate of interest r, the rate of productivity growth G^X and the rate of separation δ. While this is not an analysis of a policy scheme, it is of relevance in the current context, as policy may affect these variables, for example through fiscal policies, government investment policies etc. We vary the discount factor so as to reflect changes of 1 percentage point per quarter in the effective discount rate (r^*, where $\Phi = \frac{1}{r^*}$). Note the contradictory effects at work here: higher discounting lowers the part of the wage bargain which depends on the future and hence leads to lower wages (a 2 percentage points reduction). Therefore per-period match dividends (π) rise. However the asset value of the match ($Q\Phi\pi$) declines by 1.8 percentage points because the reduction in Φ dominates the rise in π (as well as the rise in Q). Consequently vacancy creation declines leading to an increase in unemployment and in its duration. The increase, however, is relatively small. Employment becomes more persistent and the volatility of the key variables declines. Hence a high discount rate environment makes the market less “flexible.”

6.2 Dynamic Paths

The quantitative analysis permits the derivation of the system’s dynamic path. Figure 4 shows in six panels the dynamic paths followed by all key variables when moving from one steady state to another. These paths are derived from computation of the saddle path of the log-linearized system (26), when all exogenous variables are held at their steady state values. The figures show two cases: a drop of 1 percentage point in unemployment (from the baseline of 7.2% to 6.2%) and a drop of 2 percentage points (to 5.2%). These drops are generated by an appropriate change in any of the policy parameters. It turns out that the paths appear almost identical across policy schemes, so we report the “representative case.” One difference that does exist is that a τ_Θ policy generates a decline in λ (movement from A to B in panel (a) of Figure 1) while the other policy tools generate an increase in λ (movement from A to C in panel (a) of Figure 1); consequently s is affected. We depict the cases of a τ_Θ policy and of a τ_N policy for the paths of λ and of s. For “jumping” variables the figures show the initial point and the path following the jump.

Figure 4

In all cases vacancies jump upwards initially and subsequently continue to increase gradually. The matching probabilities P and Q reflect the jump in vacancies and the subsequent change in both vacancies and unemployment. These dynamics imply counter-clockwise paths in $u-v$ space. In the case of a τ_Θ policy, λ initially jumps downwards and then continues to drop. In the case of a τ_N policy, λ initially jumps upwards and then drops gradually to its new higher level. Hence in the latter case match asset values “overshoot” their long term values. The behavior of the wage share s reflects the movement in P and λ as it is a positive function of both (see equation (21)). In the τ_Θ policy case s initially drops as the effect of the decline in λ dominates the rise in P. Later on s rises as the latter effect (P rising) dominates the former effect (λ continuing to fall). In the τ_N policy case s initially rises as both λ and P rise. Later on s continues to rise as the effect of P rising dominates the effect of λ which falls. The "overshooting" of λ has to do with this behavior of wages: with $\frac{v}{u}$ rising, the workers' hazard P rises and with it the wage. Hence firms' profits are eroded and so are asset values λ. Thus as $\frac{v}{u}$ is moving to its new, higher value, λ is falling. In the τ_N policy case the new steady state has a higher match asset value because of a higher surplus. Hence in order to decline during transition it needs to initially overshoot its new level.

The figures show that as time passes, the speed of convergence slows down. Convergence is faster in the case of a 2 percentage point drop in unemployment, as the change in the policy parameter makes unemployment less persistent: in the case of a 1 percentage point drop in unemployment, it takes 4.6 quarters to eliminate half the percentage deviation from the new steady state; in the case of a 2 percentage point drop, it takes 3.7 quarters. It then takes about 20 quarters till full convergence. The differential speed depends on the degree to which policy makes vacancy creation respond more to changes in match dividends.

6.3 Policy Effectiveness

What is the effectiveness of each of the policy instruments described above in reducing unemployment? Table 3 – based on the computations of Table 2 – reports the outcome when each policy instrument, except for ρ, is used with outlays equal to 1% of output. The table shows the value of the policy instrument used to carry out the policy and the changes in the key variables in terms of percentage points.

Table 3

Note that in all cases unemployment declines as vacancy rates increase and thus P increases and Q falls. However the other variables – match asset values, half-life statistics and the moments of persistence and co-movement – do not move in the same direction, as can be seen by comparing the movement from A to B and from A to C in panel (a) of Figure 1.

The main feature which stands out from the table is that hiring subsidies are much more effective than employment subsidies or changes in payroll taxation. For the same government outlays unemployment declines by 1.8 percentage points in the hiring subsidies case, compared to a 0.1 percentage point decline in the other cases. For the other variables the differences in effects are of similar order of magnitude. The reason for this outcome relates to the point discussed above of 'leakage' of the subsidy into wages.

Other differences between policy schemes pertain to the amount of increase in gross wages: a hiring subsidy induces a rise in the workers' hazard rate thereby increasing wages; wages rise even more with an employment subsidy, because in addition to the hazard rate increase there is also an increase in the match surplus. Gross wages decline with the decrease in the payroll tax: while the hazard rate increase has a positive effect on wages, there is an offsetting effect through the fall in the workers share (η) of the surplus.

Note that we have not considered unemployment benefits policy in this comparison, as benefits need to be *reduced* in order to reduce unemployment. This is so because a reduction in ρ reduces the workers' threat point and hence reduces their wages. Consequently match dividends rise and firms open more vacancies. Thus this is a policy where unemployment and public expenses *fall* at the same time.

6.4 The Case of No Policy Intervention

It is of interest to look at labor market outcomes in the absence of government intervention. Table 4 reports four cases: the no-intervention case where all policy parameters are set to zero, the case where there is only payroll taxation (set to the baseline value), the case where the only policy intervention is unemployment benefits (set again at the baseline) and the baseline case.

Table 4

The no-intervention case is characterized by substantially lower unemployment (a reduction of 2.3 percentage points), a higher vacancy rate, and higher per-period profits and match asset values. Note that this comparison highlights the difference between equilibrium outcomes with frictions (the natural rate of unemployment, for example, is about 5%) and outcomes with policy measures added to this environment (over 7% natural unemployment). These significant differences indicate that policy does play a substantial role, over and beyond that played by the frictions themselves. The underlying reason is that policy at the baseline generates an increase in wages relative to the no intervention case through both payroll taxation and payment of unemployment benefits. Higher wages erode profits and hence vacancy creation. The last two columns of the table demonstrate that the difference is largely due to unemployment benefits; this finding is consistent with the results of Tables 2 and 3.

Policy can also recreate the no-intervention outcome, at least with respect to the rates of unemployment and vacancies. Computations akin to those undertaken in Table 2 show that, for example, a hiring subsidy of 51.5% reproduces the no-intervention outcome when added to the other policy variables at their baseline values (i.e. $\tau_W = 0.28$ and $\rho = 0.4$).

6.5 Budget Constraints

The analysis so far has focused on changes in one policy instrument at a time, comparing policy moves that have the same cost. We shall now look at the effects of multiple changes and considerations related to the government budget constraint. In general the government has the following constraint:

$$\tau_N - \tau_W s + \tau_\Theta \widetilde{\Gamma} + \rho s \left(\frac{U}{N}\right) = T \tag{29}$$

where:

$$\widetilde{\Gamma} = \frac{\Theta}{1+\gamma}(\psi \left(\frac{V}{N}\right) + (1-\psi)\left(\frac{M}{N}\right))^{1+\gamma}$$

The constraint is written in terms of output. It says that government expenditures less revenues total some amount $T \lesseqgtr 0$. Thus, for example, the sum of the employment subsidy, the hiring subsidy and unemployment benefit payments, less payroll tax receipts, has to equal T.

The government may combine equation (29) with equations (19) and (23) to solve for a targeted labor market outcome, such as the rate of unemployment $\frac{U}{N}$, and for the value of the policy instruments. As the government has four instruments, it can set two of them arbitrarily and solve the three equations for the other two instruments and for the vacancy rate $\frac{V}{N}$ (assuming that it is the unemployment rate which is targeted). Note that this solution entails firm's optimization, and that with changes in policy, firms re-optimize. Thus the government can construct schedules for the values of the policy instruments, given an unemployment target, that withstand the Lucas critique.

This analysis may be undertaken in numerous ways. We focus here on one real-world relevant case whereby policy aims at lowering the unemployment rate. Denoting by 0 the steady state value before the change and by 1 the value after the change, the following equation captures the above constraint, assuming a fixed T:

$$(\tau_N^1 - \tau_N^0) - (\tau_W^1 s^1 - \tau_W^0 s^0) + (\tau_\Theta^1 \widetilde{\Gamma}^1 - \tau_\Theta^0 \widetilde{\Gamma}^0) + (\rho^1 s^1 \left(\frac{U}{N}\right)^1 - \rho^0 s^0 \left(\frac{U}{N}\right)^0) = 0 \qquad (30)$$

We implement the analysis as follows: we take the baseline values of Table 1 as the values for the variables and the parameters at steady state 0; we set an unemployment target $\left(\frac{U}{N}\right)^1$; we then use (19), (23) and (30) to solve for $\left(\frac{V}{N}\right)^1$ and two policy instruments, setting the other two at arbitrary levels. Intuitively the idea is to set the policy instruments so that the vacancy creation curve will intersect the Beveridge curve at the desired unemployment rate and at the same time satisfy the budget constraint. As two out of the four policy instruments may be set arbitrarily, a full taxonomy is too long to report. Table 5 reports the case where two instruments are left at their baseline values and the other two are set so that the rate of unemployment $\frac{U}{L}$ drops by one percentage point from 7.2% at the baseline to 6.2%. The table reports the outcome for all endogenous variables at the steady state.

Table 5

The key numbers in the table – indicated in bold in the top two rows – are the values of the two policy instruments under consideration. These come from the solution to the set of equations elaborated above, i.e. they are solved endogenously. In all cases policy encourages vacancy creation raising it from 5.8% at the baseline to 6.2%. Unemployment falls to its targeted value as the economy moves up the Beveridge curve. Consequently the workers' hazard (P) rises and the firms' hazard (Q) falls. These values are the same for all cases examined. The change in profits (both per period π and the asset values $Q\Phi\pi$) and the pre-tax wage share (s) varies across cases. This is so because the different policy moves affect the surplus (via τ_N) and the wage parameters (η and ω) in different ways.

In three cases (columns 1-3) a hiring subsidy is used to lower marginal costs. The subsidy is financed by an employment tax or an increase in income tax or a reduction in unemployment benefit payments. For a one percentage point reduction in the unemployment rate a hiring subsidy of around 20% of hiring costs is needed, financed by tax increases of about 0.5% of output. Note that unemployment falls in cases 1 and 2 despite the tax increases because the hiring subsidy is more effective than the tax instruments. In terms of panel (a) of Figure 1 the hiring subsidy makes the marginal cost curve move downwards. The tax increases shift the asset value curve downwards and benefits reduction shift the latter curve upwards. The simulation reveals that the government cannot reduce unemployment using an employment subsidy or a reduction in payroll taxes financed by a hiring tax. While we allowed for $\tau_\Theta < 0$ with $\tau_N > 0$ or $\tau_W^1 s^1 - \tau_W^0 s^0 > 0$ no such solution was obtained with the baseline model. The reason for this result has again to do with the relative effectiveness of the different policy instruments.

In three cases (columns 3, 4 and 5) unemployment benefit payments are reduced. This in itself operates to reduce unemployment. However maintaining the budget constraint (revenue-neutrality) means increasing expenditures (either on hiring or employment subsidies or reducing the payroll tax). Note that the policy move considered in column 5 – simultaneous reduction in benefits and in payroll taxes – is one that is often advocated. Note too that because the employment subsidy and the reduction in the payroll tax (columns 4 and 5) are not very effective policy moves, a bigger reduction in benefit payments is required in these cases relative to the case where a hiring subsidy is used (column 3). In the former, a reduction of 13 percentage points in the replacement ratio is needed, while in the latter a 2 percentage point reduction is sufficient. The implication of columns 4 and 5 is that an employment subsidy or a reduction in payroll taxes may be effective in generating a decline in unemployment, when financed by a reduction in benefit payments.

7 Conclusions

The paper presented an empirically-grounded model of the effects of policy in the presence of labor market frictions. The model emphasizes the following mechanisms: firms decide on job vacancy creation by equating marginal costs of forming a match with expected marginal gains from the match. Matching processes determine how many vacant jobs will be matched to workers in a given period thereby reducing unemployment. Concurrently, unemployment rises through labor force growth and worker separation from jobs. Labor market equilibrium is attained when these mechanisms are in dynamic equilibrium. Shocks to the system come from changes in productivity growth and in the real rate of interest, which alter expected marginal match dividends, and from changes in labor force growth. Policy affects job creation by reducing marginal costs through hiring subsidies or by increasing the expected marginal value of the match, through employment subsidies or through policy measures that reduce wages. The latter operate to change the workers' threat point in the wage bargain and their effective bargaining strength. The calibrated model, using VAR estimates of the dynamics of the exogenous variables, fits both data averages of the variables and their business cycle moments.

The simulation analysis has quantified the effects of policy measures on the rates of unemployment and vacancies, their duration, firms' match dividends (both per period and the expected present value) and workers' wages. The main conclusions from the quantitative analysis are:

(i) Hiring costs and unemployment benefits have substantial effects on labor market outcomes. Thus, provision of hiring subsidies or reduction in benefits have important consequences for the major variables. These results are consistent (though they do not constitute direct evidence or proof) with the view that high European unemployment is due to high hiring costs and generous unemployment benefits.

(ii) Employment subsidies or payroll tax reductions are not very effective policy instruments as they "leak" into increased wages. The share of the workers in the wage bargain is important for the effectiveness of these policy measures.

(iii) Policy has effects not only on steady state outcomes but also on the stochastic behavior of key variables. Measures that reduce unemployment also reduce its persistence and increase the volatility of vacancies. It was shown how to compute the value of policy measures under budget constraints.

(iv) Policy might lead to high equilibrium unemployment, relative to the case where there is no government intervention. The reason is that it affects wages and hence firms' profits and vacancy creation. It was shown how unemployment may be reduced, even to non-intervention levels, mainly through the use of hiring subsidies and reduction of unemployment benefits.

Appendix A

The Wage Solution

The wage solution to the Nash bargaining problem (10) is given by:

$$\xi \frac{\partial J_t^N}{\partial W_t}(J_t^F - J_t^V) + (1-\xi)\frac{\partial J_t^F}{\partial W_t}(J_t^N - J_t^U) = 0 \tag{31}$$

where $\left(J_t^F - J_t^V\right)$ is the firm's net value of the match, $\left(J^N - J^U\right)$ is the worker's net value of the match (J^N being the gross value and J^U being the value of unemployment) and ξ is the worker's share of the match surplus.

Following equations (5) and (6) a match that is formed and is to begin production at time t is worth to the firm:

$$J_t^F = \frac{\partial F_t}{\partial N_t}(1+\tau_N) - W_t - \frac{\partial \Gamma_t}{\partial N_t} + E_t \frac{(1-\delta)}{1+r_t} J_{t+1}^F \tag{32}$$

Note that according to the same equations $J_t^V = 0$.

For the unemployed worker the present value of unemployment consists of the sum of (i) the value of unemployment at time t, denoted b_t; and (ii) the expected future value which takes into account the probability of matching into employment the next period, $P_{t,t+1} = \frac{M_{t,t+1}}{U_t}$, and the continuation value of employment J^N :

$$J_t^U = b_t + E_t \frac{1}{1+r_t}\left[P_{t,t+1} J_{t+1}^N + (1 - P_{t,t+1}) J_{t+1}^U\right] \tag{33}$$

Similarly the present value of employment consists of the sum of (i) the net wage at time t; and (ii) the expected future value which takes into account the probability of separating from employment into unemployment in the next period, δ, and the continuation value of unemployment J^U :

$$J_t^N = (1-\tau_W) W_t + E_t \frac{1}{1+r_t}\left[(1-\delta) J_{t+1}^N + \delta J_{t+1}^U\right] \tag{34}$$

We postulate, as explained in the text:

$$b_t = z\frac{F_t}{N_t} + \rho(1-\tau_b\tau_W)W_t \tag{35}$$

Inserting (32- 35) into (31) and solving yields:

$$\begin{aligned} W_t \;&=\; \frac{\xi(1-\tau_W)}{(1-\tau_W)-(1-\xi)\rho(1-\tau_b\tau_W)}\left(\frac{\partial F_t}{\partial N_t}(1+\tau_N) - \frac{\partial \Gamma_t}{\partial N_t} + E_t P_{t,t+1}\frac{J_t^F}{1+r_t}\right) \\ &+\frac{(1-\xi)}{(1-\tau_W)-(1-\xi)\rho(1-\tau_b\tau_W)} z\frac{F_t}{N_t} \end{aligned} \tag{36}$$

Denote:

$$\eta \equiv \frac{\xi(1-\tau_W)}{(1-\tau_W)-(1-\xi)\rho(1-\tau_b\tau_W)}$$

$$\omega \equiv \frac{(1-\xi)}{(1-\tau_W)-(1-\xi)\rho(1-\tau_b\tau_W)}$$

Using equations (5) and (6) to replace $E_t\frac{J_t^F}{1+r_t}$ by Λ_t, we get:

$$W_t = \eta\left(\frac{\partial F_t}{\partial N_t}(1+\tau_N) - \frac{\partial \Gamma_t}{\partial N_t} + E_t P_{t,t+1}\Lambda_t,\right) + \omega z\frac{F_t}{N_t} \tag{37}$$

which is equation (12) in the main text.

Appendix B

The Derivation of the Log-Linear Dynamic System and Its Solution

In order to define the dynamics of the model, we log-linearize it around its steady state. The approach we use consists of the following steps:

(i) Using the F.O.C, we characterize the non-stochastic steady state. The latter is given by equations (19) and (22).

(ii) The deterministic version of the F.O.C of the firm's problem, including the flow equation for employment, is linearly approximated in the neighborhood of this steady state.

(iii) This yields a first-order, linear, difference equation system, which solution gives the dynamic path of the control and the endogenous state variables as a function of a sequence of the exogenous variables. We use the postulated stochastic set-up for the exogenous variables as given by equations (25).

(iv) Working from a certainty equivalence perspective, the deterministic sequences for the exogenous variables are then replaced with the conditional expectations at time t for the afore-cited stochastic processes.

In what follows we present an abridged derivation of the approximated dynamic system. For each variable Y we denote $\widehat{Y}_t = \frac{Y_t - Y}{Y} \approx \ln Y_t - \ln Y$ where Y is the steady state value.

We begin with (5). This is approximated as follows:

$$\widehat{\lambda}_t + \left(\gamma - \frac{\sigma n}{1-n}(1-(\gamma+1)\varphi)\right)\widehat{n}_t = (\gamma + \sigma - \sigma(\gamma+1)\varphi)\,\widehat{v}_t \tag{38}$$

where:

$$\varphi = \frac{(1-\psi)Q}{\psi + (1-\psi)Q}$$

Using the F.O.C (6), inserting the wage solution, dividing throughout by $\frac{F_{t+1}}{N_{t+1}}$,denoting $G^X_{t+1} \equiv \frac{F_{t+1}/N_{t+1}}{F_t/N_t}$ and approximating, we get:

$$-\left[\begin{array}{c} \beta\eta P\lambda\frac{n}{1-n}(1-\sigma) \\ +\beta\Theta(1-\eta)(1-\tau_{\Theta})\left(1-\frac{\alpha}{1+\gamma}\right)\left(\psi\frac{v}{n}+(1-\psi)\frac{m}{n}\right)^{\gamma+1}(1+\gamma)\left[1+\frac{\sigma\varphi n}{1-n}\right] \end{array}\right]\widehat{n}_{t+1} \tag{39}$$

$$
\begin{aligned}
& +\left[(1-\delta)\beta\lambda-\beta\eta P\lambda\right]\widehat{\lambda}_{t+1}-\frac{\lambda}{G^X}\widehat{\lambda}_t \\
= & \left[\begin{array}{c} \beta\eta P\lambda(1-\sigma) \\ -\beta\Theta(1-\eta)(1-\tau_\Theta)\left(1-\frac{\alpha}{1+\gamma}\right)\left(\psi\frac{v}{n}+(1-\psi)\frac{m}{n}\right)^{\gamma+1}(1+\gamma)\left[1-\varphi+\varphi(1-\sigma)\right] \end{array}\right]\widehat{v}_{t+1} \\
& -\frac{\lambda}{G^X}\widehat{G}^X_{t+1} \\
& -\left[\beta\pi+(1-\delta)\beta\lambda\right]\widehat{\beta}_{t+1}
\end{aligned}
$$

Dividing (4) by L_t throughout and approximating the dynamic equation for employment we get:

$$
\begin{aligned}
& \left[nG^L\right]\widehat{n}_{t+1}-\left[(1-\delta)n-Qv\sigma\frac{n}{1-n}\right]\widehat{n}_t \\
= \; & Qv(1-\sigma)\widehat{v}_t-nG^L\widehat{G}^L_{t+1}
\end{aligned}
\tag{40}
$$

where we define 1+the growth rate of the labor force as:

$$
G^L_{t+1}\equiv\frac{L_{t+1}}{L_t} \tag{41}
$$

Equations (38), (39) and (40) can be combined to yield the system approximated around the steady state equation analyzed in sub-section 2.5:

$$
\begin{bmatrix} \widehat{n}_{t+1} \\ \widehat{\lambda}_{t+1} \end{bmatrix} = B\begin{bmatrix} \widehat{n}_t \\ \widehat{\lambda}_t \end{bmatrix}+C\begin{bmatrix} \widehat{G}^X_{t+1} \\ \widehat{G}^L_{t+1} \\ \widehat{\beta}_{t+1} \end{bmatrix} \tag{42}
$$

The dynamic system (42) is solved by the regular methods of difference equations (see for example Blanchard and Kahn (1980)). Saddle path stability holds true if one of the characteristic roots of this system is above 1 and one is below 1 in absolute value. This condition may be re-written as:

$$
\det B-trB+1<0 \tag{43}
$$

We have verified for each case simulated that this condition holds true.

The solution yields a difference equation for $\widehat{n}_{t+1}$ given an initial $\widehat{n}_0$ that is consistent with the transversality condition and is expressed by:

$$\widehat{n}_{t+1} = \upsilon_1 \widehat{n}_t + \kappa_1 x_t + \kappa_2 \sum_{j=0}^{\infty} \upsilon_2 x_{t+j+1} \tag{44}$$

where κ_1 and κ_2 are functions of the underlying parameters, and

$$x_t = \begin{bmatrix} \widehat{G}_t^X \\ \widehat{G}_t^L \\ \widehat{\beta}_t \end{bmatrix}$$

Recall that the stochastic behavior of the exogenous variables is given by:

$$x_{t+1} = \Pi x_t + \Sigma_{t+1} \tag{45}$$

Note that the parameters κ_1 and κ_2 include products of the exogenous variables VAR coefficient matrix Π as we replace the sequence of future values of x by their expected values using (45).

In order to characterize the properties of the dynamic path of $\widehat{n}$ in the non-stochastic case, set all exogenous variables equal to their steady state values and so the dynamics are given by:

$$\widehat{n}_{t+1} = \upsilon_1 \widehat{n}_t \tag{46}$$

The solution of the system enables us to solve for the other variables of interest.

Define vectors of state variables h_t and their innovations ϵ_t :

$$h_t = \begin{pmatrix} \widehat{n}_t \\ x_t \end{pmatrix} \qquad \epsilon_t = \begin{pmatrix} 0 \\ \Sigma_t \end{pmatrix} \tag{47}$$

Thus:

$$h_{t+1} = G h_t + \epsilon_{t+1} \tag{48}$$

where

$$G=\begin{pmatrix} \upsilon_1 & \Upsilon_{nx} \\ 0 & \Pi \end{pmatrix}. \tag{49}$$

Υ_{xy} denotes the saddle path slope for any two variables x and y. The co-state and control variables are functions of this state vector:

$$\begin{aligned} \widehat{\lambda}_t &= \begin{pmatrix} \Upsilon_{\lambda n} & \Upsilon_{\lambda x} \end{pmatrix} s_t \\ \widehat{\upsilon}_t &= \begin{pmatrix} \Upsilon_{vn} & \Upsilon_{vx} \end{pmatrix} s_t \end{aligned} \tag{50}$$

The other variables in the model - u, m, s - shall be contained in the vector f_t are expressible as a linear combination of the controls, states and exogenous variables:

$$\begin{aligned} f_t &= F_v \widehat{\upsilon}_t + F_n \widehat{n}_t + F_x x_t \\ &= \left[F_v \begin{pmatrix} \Upsilon_{vn} & \Upsilon_{vx} \end{pmatrix} + \begin{pmatrix} F_n & F_x \end{pmatrix} \right] h_t \end{aligned} \tag{51}$$

Therefore it is possible to represent all the variables except the state and exogenous variables in the form:

$$\begin{pmatrix} \widehat{\lambda}_t \\ \widehat{\upsilon}_t \\ f_t \end{pmatrix} = H h_t \tag{52}$$

Second moments may be derived as follows:

$$\begin{aligned} E(h_t h_t') &= \Gamma_0 \\ E(h_t h_{t-i}') &= E\left[(G^i s_{t-i} + \epsilon_t + \ldots + G^{i-1} \epsilon_{t-i+1}) h_{t-i}' \right] \\ &= G^i \Gamma_0 \end{aligned} \tag{53}$$

$$\begin{aligned} E\left[h_t \begin{pmatrix} \lambda_t \\ u_t \\ f_t \end{pmatrix}' \right] &= E(h_t h_t' H') \\ &= \Gamma_0 H'. \end{aligned} \tag{54}$$

We use the coefficient matrix Π and the variance-covariance matrix of Σ, estimated by the reduced-form VAR, and the solution of the model (υ_1 and the Υs) given in terms of the model's parameters to compute Γ_0, G and H.

Appendix C

Data: Sources and Definitions

All data are quarterly for the periods noted. The following table lists definitions and original sources.

Series	Definition and Sources
F	Real business sector GDP
	CBS, 1964-1995
L, N, U	Labor force, business sector employment, and unemployment
	CBS, 1960-1995
r	Real interest rate on bank credit
	= nominal rate, deflated by business sector GDP deflator inflation
	BOI, 1972-1995
V	Vacancies
	ES, 1975-1989
M	Filled Vacancies
	ES, 1975-1989

Notes:

CBS=Central Bureau of Statistics

BOI=Bank of Israel

ES=Employment Service

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Table 1

Baseline Model

a. Parameters

function	symbol	value
hiring	Θ	1,015,940
	γ	4.4
	ψ	0.3
separation	δ	0.0406
matching	μ	0.73
	σ	0.3
wage	ξ	0.17
production	α	0.68
non-pecuniary income	z	0.09

Note: The structural estimates reported in Yashiv (2000 a,b) are the source for the above numbers except the scale parameters of the hiring cost function (Θ) and of the matching function (μ) which are set so that the solution of the system will yield the sample average values of $\frac{U}{N}$ and $\frac{V}{N}$ discussed in the text.

b. Exogenous Variables

variable	symbol	value
interest rate	r	0.01
productivity growth (gross rate)	G^X	1.005
labor force growth (gross rate)	G^L	1.006

Note: The numbers are sample averages, in quarterly terms.

c. Policy Variables

policy measure	**symbol**	**value**
hiring subsidies	τ_Θ	0
employment subsidy	τ_N	0
payroll tax	τ_W	0.28
replacement ratio	ρ	0.4
benefits taxes	τ_b	1

Note: The numbers are average policy parameter values, based on the data.

d. Steady State Values

	symbol	**value**
unemployment rates	$\frac{U}{N}$	0.0776
	$\frac{U}{L}$	0.0720
vacancy rate	$\frac{V}{N}$	0.0582
matching rate	$\frac{M}{N}$	0.0466
workers' hazard	$P = \frac{M}{U}$	0.60
firms' hazard	$Q = \frac{M}{V}$	0.80
wage share	$s = \frac{WN}{F}$	0.67
per-period match dividends	π	0.094
expected asset value of the match	$Q\Phi\pi$	1.65

Note: The numbers for $\frac{U}{N}$, $\frac{U}{L}$, P and Q are sample averages. The remaining numbers are obtained from the solution of the model in the steady state.

e. Dynamic Path

υ_1	0.8548
half-life	4.42

f. Business Cycle Dynamics

		model	**data**
persistence	$\rho(\widehat{n}_t, \widehat{n}_{t-1})$	0.97	0.95
co-movement	$\rho(\widehat{u}_t, \widehat{v}_{t)}$	-0.63	-0.47
	$\rho(\widehat{s}_t, \widehat{n}_{t)}$	0.53	0.27
	$\rho(\widehat{n}_t, \widehat{G}_t^X)$	0.01	-0.01
volatility	$\frac{\text{std}\,\widehat{v}}{\text{std}\,\widehat{n}}$	9.6	17.8
	$\frac{\text{std}\,\widehat{s}}{\text{std}\,\widehat{n}}$	19.2	1. 8

Table 2

Policy Effects

I Hiring Subsidies/Taxes

a. Steady State

	symbol	**baseline (%)**	$\tau_\theta = 42.92\%$	$\tau_\theta = -72.16\%$
unemployment rates	$\frac{U}{N}$	7.8	5.7	10.8
	$\frac{U}{L}$	7.2	5.4	9.7
vacancy rate	$\frac{V}{N}$	5.8	6.7	5.1
workers' hazard	$P = \frac{M}{U}$	60	82	43
firms' hazard	$Q = \frac{M}{V}$	80	70	92
wage share	$s = \frac{WN}{F}$	67.00	67.25	66.66
per-period match dividends	π	9.4	7.0	12.6
expected asset value of the match	$Q\Phi\pi$	165	108	255

b. Dynamic Path

	baseline	$\tau_\theta = 42.92\%$	$\tau_\theta = -72.16\%$
υ_1	0.85	0.80	0.90
half-life	4.4	3.1	6.3

c. Business Cycle Features

		baseline	$\tau_\theta = 42.92\%$	$\tau_\theta = -72.16\%$
persistence	$\rho(\widehat{n}_t, \widehat{n}_{t-1})$	0.970	0.958	0.979
co-movement	$\rho(\widehat{u}_t, \widehat{v}_t)$	-0.63	-0.65	-0.61
	$\rho(\widehat{s}_t, \widehat{n}_t)$	0.53	0.59	0.47
	$\rho(\widehat{n}_t, \widehat{G}_t^X)$	0.01	0.01	0.01
volatility	$\frac{\text{std } \widehat{v}}{\text{std } \widehat{n}}$	9.6	11.8	7.9
	$\frac{\text{std } \widehat{s}}{\text{std } \widehat{n}}$	19.2	24.4	15.3

II Employment Subsidies/Taxes

a. Steady State

	symbol	baseline (%)	$\tau_N = 1\%$	$\tau_N = -1\%$
unemployment rates	$\frac{U}{N}$	7.76	7.69	7.83
	$\frac{U}{L}$	7.20	7.14	7.26
vacancy rate	$\frac{V}{N}$	5.82	5.84	5.80
workers' hazard	$P = \frac{M}{U}$	60.0	60.5	59.4
firms' hazard	$Q = \frac{M}{V}$	80.0	79.7	80.3
wage share	$s = \frac{WN}{F}$	67.0	67.7	66.2
per-period match dividends	π	9.40	9.48	9.34
expected asset value of the match	$Q\Phi\pi$	165.4	165.9	164.8

variations in the bargaining parameter

	$\tau_N = 1\%$	$\tau_N = -1\%$	$\tau_N = 1\%$	$\tau_N = -1\%$
	$\xi = 0.1$	$\xi = 0.1$	$\xi = 0.3$	$\xi = 0.3$
$\frac{U}{L}$	7.10	7.31	7.17	7.23
s	67.7	66.3	67.7	66.3
$Q\Phi\pi$	166.3	164.4	165.6	165.1

b. Dynamic Path

	baseline	$\tau_N = 1\%$	$\tau_N = -1\%$
υ_1	0.8548	0.8535	0.8561
half-life	4.42	4.37	4.46

variations in the bargaining parameter

	baseline	$\tau_N = 1\%$	$\tau_N = -1\%$	**baseline**	$\tau_N = 1\%$	$\tau_N = -1\%$
	$\xi = 0.1$	$\xi = 0.1$	$\xi = 0.1$	$\xi = 0.3$	$\xi = 0.3$	$\xi = 0.3$
υ_1	0.8626	0.8605	0.8649	0.8470	0.8463	0.8477
half-life	4.69	4.61	4.78	4.17	4.15	4.19

c. Business Cycle Features

		baseline	$\tau_N = 1\%$	$\tau_N = -1\%$
persistence	$\rho(\widehat{n}_t, \widehat{n}_{t-1})$	0.9703	0.9700	0.9706
co-movement	$\rho(\widehat{u}_t, \widehat{v}_t)$	-0.628	-0.629	-0.628
	$\rho(\widehat{s}_t, \widehat{n}_t)$	0.529	0.531	0.527
	$\rho(\widehat{n}_t, \widehat{G}_t^X)$	0.01	0.01	0.01
volatility	$\frac{\text{std}\,\widehat{v}}{\text{std}\ \widehat{n}}$	9.6	9.7	9.6
	$\frac{\text{std}\,\widehat{s}}{\text{std}\ \widehat{n}}$	19.2	19.4	19.1

variations in the bargaining parameter

	baseline	$\tau_N = 1\%$	$\tau_N = -1\%$	**baseline**	$\tau_N = 1\%$	$\tau_N = -1\%$
	$\xi = 0.1$	$\xi = 0.1$	$\xi = 0.1$	$\xi = 0.3$	$\xi = 0.3$	$\xi = 0.3$
$\frac{\text{std}\,\widehat{v}}{\text{std}\ \widehat{n}}$	9.47	9.56	9.37	9.74	9.77	9.72
$\rho(\widehat{n}_t, \widehat{n}_{t-1})$	0.9720	0.9716	0.9725	0.9684	0.9683	0.9686
$\rho(\widehat{u}_t, \widehat{v}_{t)}$	-0.643	-0.644	-0.642	-0.613	-0.614	-0.613

Note: the subsidy and the tax are 1% of output each.

III Payroll taxes

a. Steady State

		baseline	$\tau_W = 26.5\%$	$\tau_W = 29.5\%$
unemployment rates	$\frac{U}{N}$	7.76	7.72	7.80
	$\frac{U}{L}$	7.20	7.16	7.24
vacancy rate	$\frac{V}{N}$	5.82	5.83	5.80
workers' hazard	$P = \frac{M}{U}$	60.0	60.3	59.7
firms' hazard	$Q = \frac{M}{V}$	80.0	79.8	80.2
wage share	$s = \frac{WN}{F}$	67.000	66.996	67.005
per-period match dividends	π	9.41	9.45	9.37
expected asset value of the match	$Q\Phi\pi$	165.37	165.73	165.03

variations in the bargaining parameter

	$\tau_W = 26.5\%$	$\tau_W = 29.5\%$	$\tau_W = 26.5\%$	$\tau_W = 29.5\%$
	$\xi = 0.1$	$\xi = 0.1$	$\xi = 0.3$	$\xi = 0.3$
$\frac{U}{L}$	7.07	7.34	7.22	7.18
s	66.984	67.017	67.003	66.997
$Q\Phi\pi$	166.60	164.08	165.15	165.60

b. Dynamic Path

	baseline		$\tau_W = 26.5\%$	$\tau_W = 29.5\%$
υ_1	0.8548		0.8541	0.8558
half-life	4.42		4.39	4.45

variations in the bargaining parameter

	baseline	$\tau_W = 26.5\%$	$\tau_W = 29.5\%$	**baseline**	$\tau_W = 26.5\%$	$\tau_W = 29.5\%$
	$\xi = 0.1$	$\xi = 0.1$	$\xi = 0.1$	$\xi = 0.3$	$\xi = 0.3$	$\xi = 0.3$
υ_1	0.8626	0.8599	0.8656	0.8470	0.8476	0.8464
half-life	4.69	4.59	4.80	4.17	4.19	4.16

c. Business Cycle Features

		baseline	$\tau_W = 26.5\%$	$\tau_W = 29.5\%$
persistence	$\rho(\widehat{n}_t, \widehat{n}_{t-1})$	0.9703	0.9701	0.9705
co-movement	$\rho(\widehat{u}_t, \widehat{v}_t)$	-0.628	-0.629	-0.628
	$\rho(\widehat{s}_t, \widehat{n}_t)$	0.529	0.530	0.528
	$\rho(\widehat{n}_t, \widehat{G}_t^X)$	0.01	0.01	0.01
volatility	$\frac{\text{std }\widehat{v}}{\text{std }\widehat{n}}$	9.60	9.64	9.57
	$\frac{\text{std }\widehat{s}}{\text{std }\widehat{n}}$	19.23	19.49	18.95

variations in the bargaining parameter

	baseline	$\tau_W = 26.5\%$	$\tau_W = 29.5\%$	**baseline**	$\tau_W = 26.5\%$	$\tau_W = 29.5\%$
	$\xi = 0.1$	$\xi = 0.1$	$\xi = 0.1$	$\xi = 0.3$	$\xi = 0.3$	$\xi = 0.3$
$\frac{\text{std }\widehat{v}}{\text{std }\widehat{n}}$	9.47	9.58	9.34	9.74	9.72	9.77
$\rho(\widehat{n}_t, \widehat{n}_{t-1})$	0.9720	0.9714	0.9727	0.968	0.969	0.968
$\rho(\widehat{u}_t, \widehat{v}_t)$	-0.643	-0.645	-0.642	-0.613	-0.613	-0.614

Note: the subsidy is 1% of output i.e. the tax reduction is $(\tau_W s)^{baseline} - \tau_W s = 0.01$; the tax increase is computed similarly.

IV Unemployment Benefits and Benefit Taxes

a. Steady State

	symbol	**baseline (%)**	$\rho = 17.33\%$	$\rho = 53.20\%$	$\tau_b = 0$
unemployment rates	$\frac{U}{N}$	7.8	6.1	9.7	10.3
	$\frac{U}{L}$	7.2	5.7	8.9	9.3
vacancy rate	$\frac{V}{N}$	5.8	6.5	5.3	5.2
workers' hazard	$P = \frac{M}{U}$	60	77	48	45
firms' hazard	$Q = \frac{M}{V}$	80	72	88	90
wage share	$s = \frac{WN}{F}$	67.00	66.77	67.16	67.2
per-period match dividends	π	9.4	11.6	7.9	7.6
expected asset value of the match	$Q\Phi\pi$	165	183	153	150

b. Dynamic Path

	baseline	$\rho = 17.33\%$	$\rho = 53.20\%$	$\tau_b = 0$
υ_1	0.8548	0.8176	0.8828	0.8886
half-life	4.42	3.44	5.56	5.87

c. Business Cycle Features

		baseline	$\rho = 17.33\%$	$\rho = 53.20\%$	$\tau_b = 0$
persistence	$\rho(\widehat{n}_t, \widehat{n}_{t-1})$	0.9703	0.9620	0.9763	0.9775
co-movement	$\rho(\widehat{u}_t, \widehat{v}_{t)}$	-0.63	-0.66	-0.61	-0.60
	$\rho(\widehat{s}_t, \widehat{n}_{t)}$	0.53	0.54	0.48	0.47
	$\rho(\widehat{n}_t, \widehat{G}_t^X)$	0.01	0.01	0.01	0.01
volatility	$\frac{\text{std}\,\widehat{v}}{\text{std}\,\widehat{n}}$	9.6	11.2	8.4	8.2
	$\frac{\text{std}\,\widehat{s}}{\text{std}\,\widehat{n}}$	19.2	27.8	13.4	24.1

V. The Discount Factor

a. Steady State

		baseline (%)	$\Phi = 28.11$	$\Phi = 17.944$
unemployment rates	$\frac{U}{N}$	7.8	7.5	8.0
	$\frac{U}{L}$	7.2	7.0	7.4
vacancy rate	$\frac{V}{N}$	5.8	5.9	5.7
workers' hazard	$P = \frac{M}{U}$	60	62	58
firms' hazard	$Q = \frac{M}{V}$	80	79	81
wage share	$s = \frac{WN}{F}$	67.0	69.1	65.0
per-period match dividends	π	9.4	7.6	11.2
expected asset value of the match	$Q\Phi\pi$	165.0	167.6	163.2

b. Dynamic Path

	baseline	$\Phi = 28.11$	$\Phi = 17.944$
υ_1	0.8548	0.8484	0.8613
half-life	4.42	4.21	4.64

c. Business Cycle Features

		baseline	$\Phi = 28.11$	$\Phi = 17.944$
persistence	$\rho(\widehat{n}_t, \widehat{n}_{t-1})$	0.9703	0.9689	0.9717
co-movement	$\rho(\widehat{u}_t, \widehat{v}_{t)}$	-0.628	-0.62875	-0.6279
	$\rho(\widehat{s}_t, \widehat{n}_{t)}$	0.529	0.533	0.525
	$\rho(\widehat{n}_t, \widehat{G}_t^X)$	0.01	0.01	0.01
volatility	$\frac{\text{std}\,\widehat{v}}{\text{std}\,\widehat{n}}$	9.6	9.8	9.4
	$\frac{\text{std}\,\widehat{s}}{\text{std}\,\widehat{n}}$	19.2	20.4	18.1

Notes:

1. $\Phi = \frac{1}{r^*}$ where r^* is the effective discount rate (note that $r^* \neq r$).
2. At the baseline $\Phi = 21.94$ which implies $r^* = 0.046$.
3. The case of $\Phi = 28.11$ implies $r^* = 0.036$.
4. The case of $\Phi = 17.94$ implies $r^* = 0.056$.

Table 3

The Effectiveness of Policy Schemes

instrument	**value (%)**	$\frac{U}{L}$	**P**	s	$\frac{V}{N}$	**Q**	$\mathbf{Q\Phi\pi}$	half-life	$\rho(\widehat{n}_t,\widehat{n}_{t-1})$	$\rho(\widehat{u}_t,\widehat{v}_{t)}$
Baseline		7.2	60	67.00	5.82	80.0	165	4.42	0.970	-0.63
τ_Θ	42.92	5.4	82	67.25	6.70	70	108	3.10	0.958	-0.65
τ_N $(\xi = 0.1)^2$	1	7.1	60.9	67.70	5.86	79.5	166.3	4.69	0.972	-0.64
τ_N $(\xi = 0.17)$	1	7.1	60.5	67.70	5.84	79.7	165.9	4.37	0.970	-0.63
τ_N $(\xi = 0.3)^2$	1	7.2	60.2	67.70	5.83	79.9	165.6	4.15	0.970	-0.61
τ_W $(\xi = 0.1)^2$	26.5	7.1	61.2	66.984	5.87	79.3	166.6	4.69	0.972	-0.64
τ_W $(\xi = 0.17)$	26.5	7.2	60.3	66.996	5.83	79.8	165.7	4.39	0.970	-0.63
τ_W $(\xi = 0.3)^2$	26.5	7.2	59.8	67.003	5.81	80.1	165.2	4.19	0.969	-0.61

Notes:

1. The table shows the value of policy instruments corresponding to outlays of 1% of output (first column) and the resulting value of the key variables and key moments in percentage points.

2. In the cases of $\xi = 0.1, 0.3$ note that the baseline itself changes (not reported here).

Table 4

The Effects of Government Intervention

	symbol	**baseline**	$\tau_W = \rho = 0$	$\tau_W = 0$	$\rho = 0$
unemployment rates	$\frac{U}{N}$	7.8	5.2	7.2	5.3
	$\frac{U}{L}$	7.2	4.9	6.7	5.1
vacancy rate	$\frac{V}{N}$	5.8	7.0	6.0	6.8
matching rate	$\frac{M}{N}$	4.7	4.7	4.7	4.7
workers' hazard	$P = \frac{M}{U}$	60	90	64	88
firms' hazard	$Q = \frac{M}{V}$	80	67	78	68
wage share	$s = \frac{WN}{F}$	67	66.56	66.94	66.62
per-period match dividends	π	9.4	13.6	10.0	13.0
expected asset value of the match	$Q\Phi\pi$	165	199	170	194

Table 5

Budget-Constrained Policy Changes

	baseline	**1**	**2**	**3**	**4**	**5**
	$\tau_N = \tau_\Theta = 0$	$\boldsymbol{\tau_N = -0.005}$	$\boldsymbol{\tau_W = 0.287}$	$\boldsymbol{\rho = 0.38}$	$\boldsymbol{\rho = 0.27}$	$\boldsymbol{\rho = 0.27}$
	$\tau_W = 0.28; \rho = 0.4$	$\boldsymbol{\tau_\Theta = 0.24}$	$\boldsymbol{\tau_\Theta = 0.24}$	$\boldsymbol{\tau_\Theta = 0.20}$	$\boldsymbol{\tau_N = 0.009}$	$\boldsymbol{\tau_W = 0.267}$
$s = \frac{WN}{F}$	0.670	0.668	0.671	0.671	0.675	0.669
π	0.094	0.08	0.08	0.09	0.11	0.11
$Q\Phi\pi$	1.65	1.33	1.34	1.41	1.76	1.76

In all cases the following obtains:

	symbol	**baseline value**	**new value**
unemployment rates	$\frac{U}{N}$	0.078	0.067
	$\frac{U}{L}$	0.072	0.062
vacancy rate	$\frac{V}{N}$	0.058	0.062
matching rate	$\frac{M}{N}$	0.047	0.047
workers' hazard	$P = \frac{M}{U}$	0.60	0.70
firms' hazard	$Q = \frac{M}{V}$	0.80	0.75

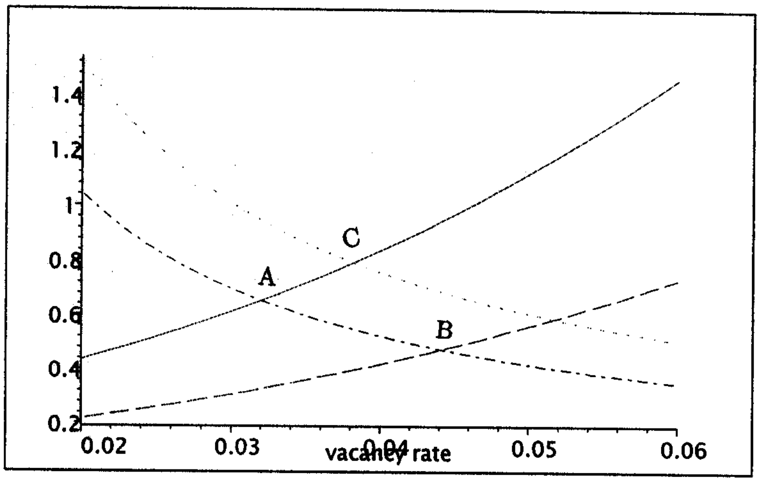

Figure 1a: Marginal Costs and Marginal Profits

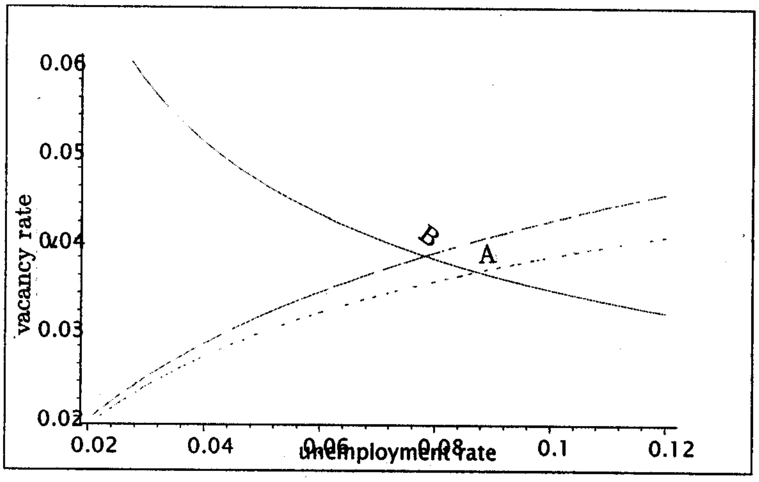

Figure 1b: Unemployment and Vacancy Rates

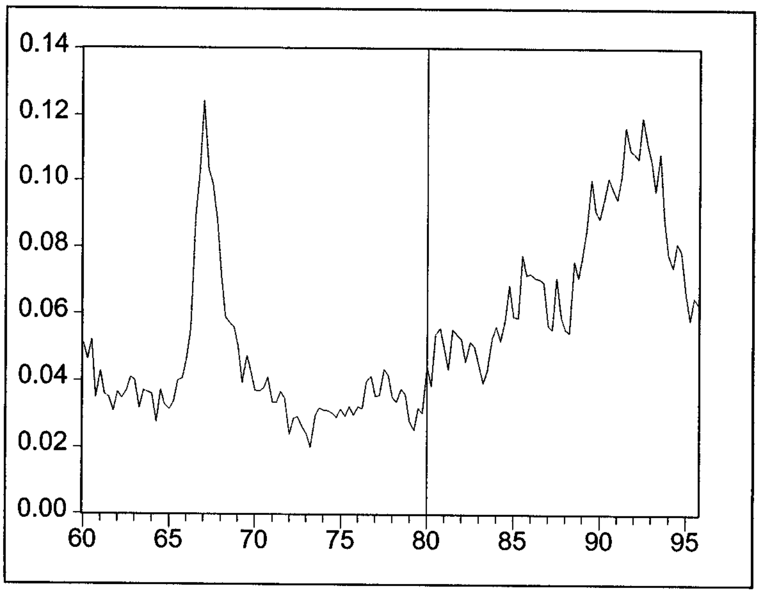

Figure 2: The Rate of Unemployment

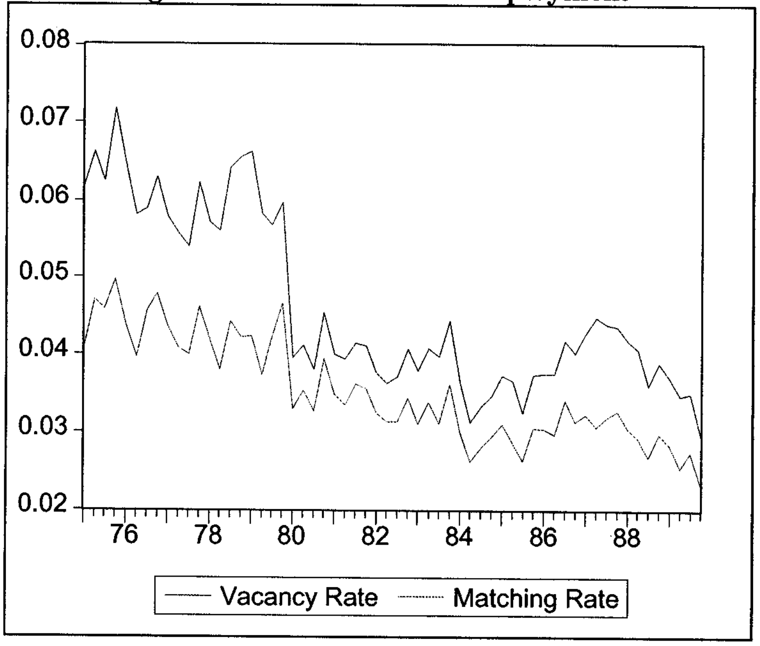

Figure 3: The Rates of Vacancies and Hiring

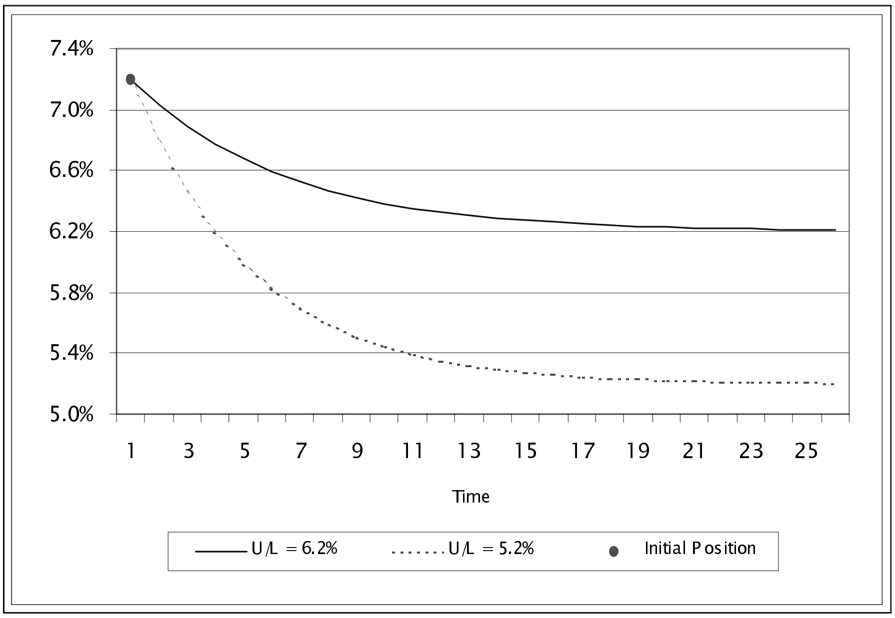

Figure 4a: $\frac{U}{L}$

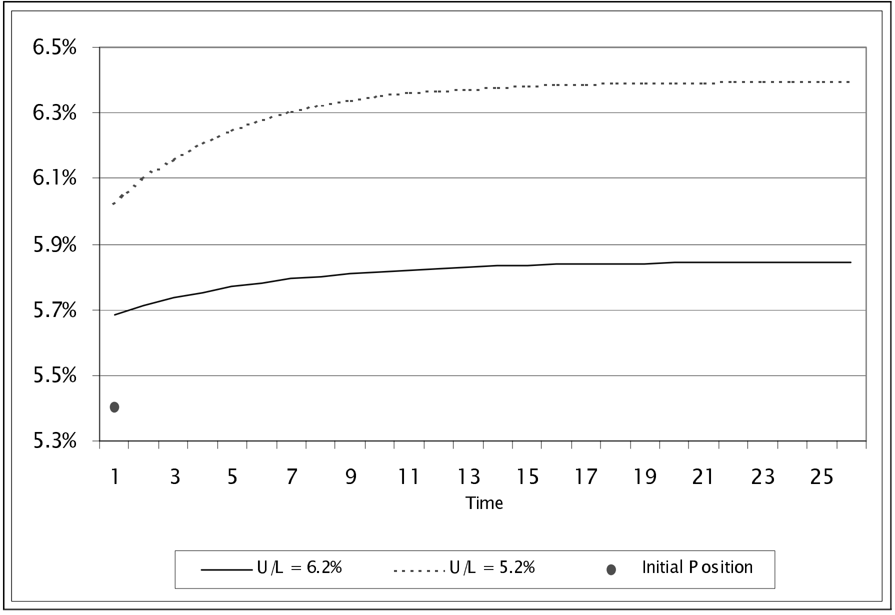

Figure 4b: $\frac{V}{L}$

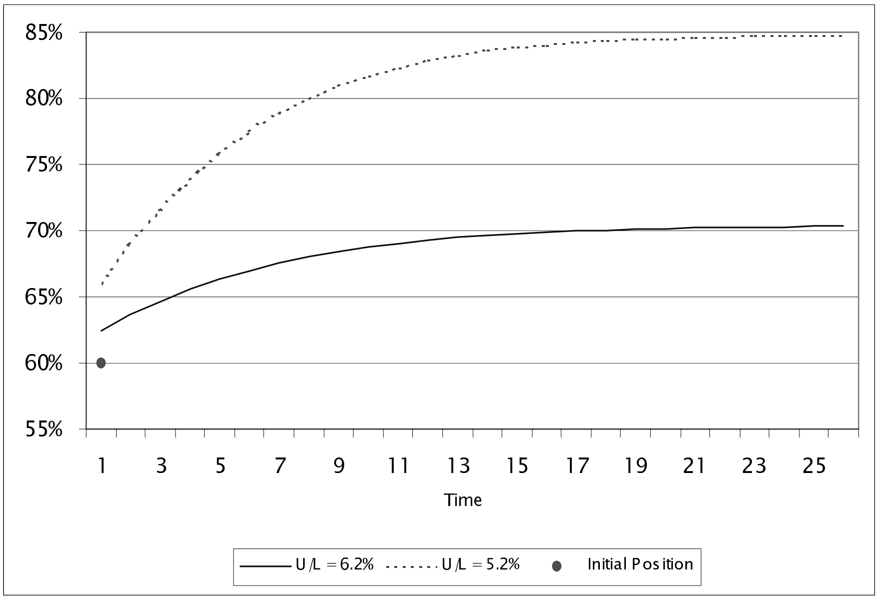

Figure 4c: P

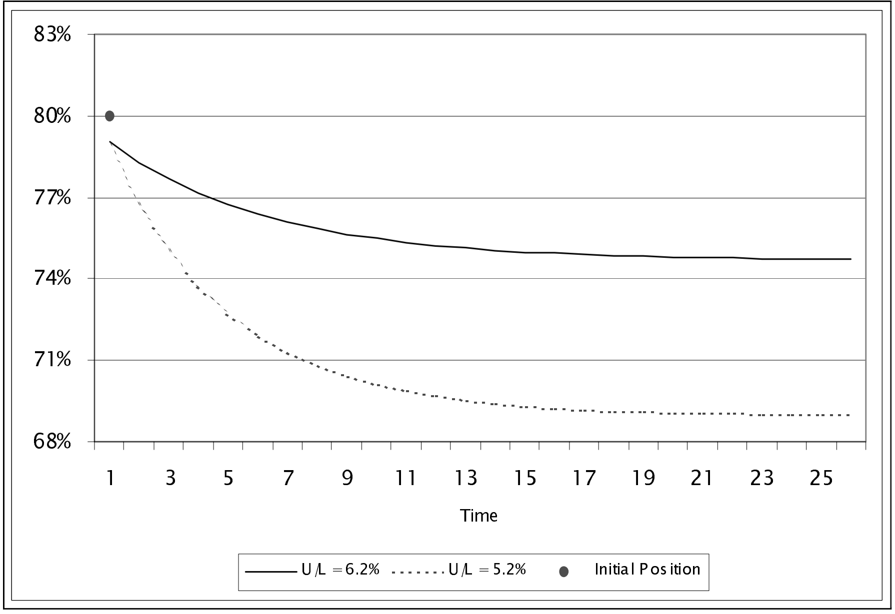

Figure 4d: Q

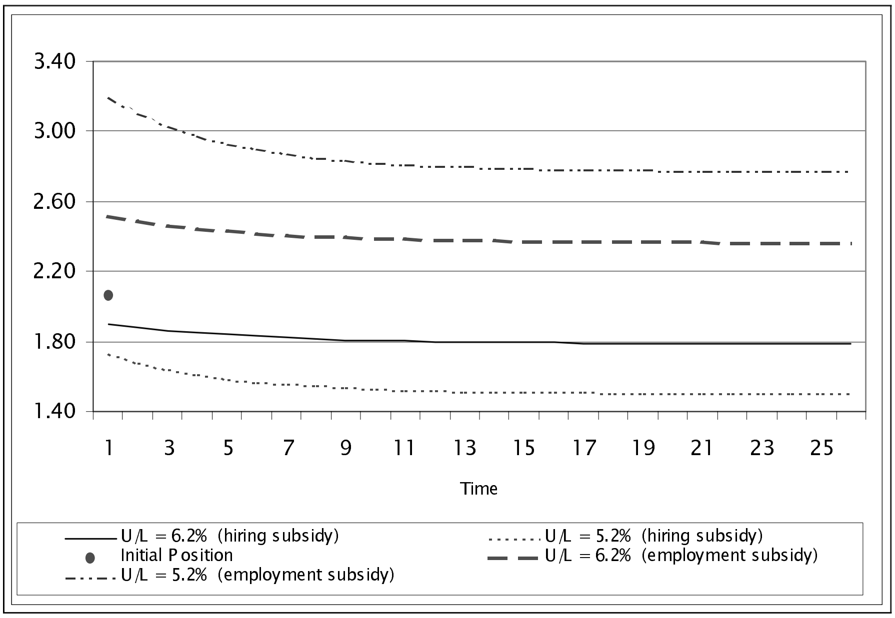

Figure 4e: λ

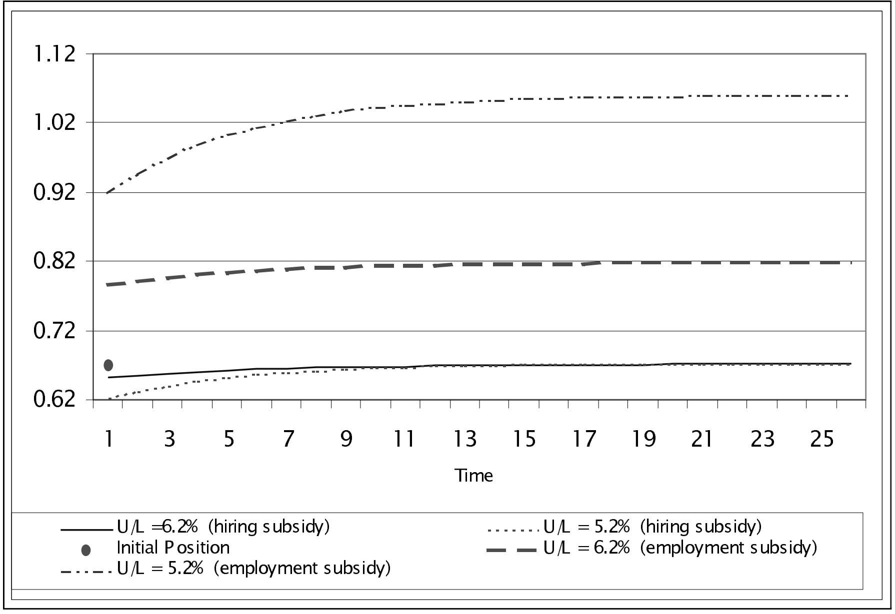

Figure 4f: s