

Burda, Michael C.; Weder, Mark

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Complementarity of Labor Market Institutions, Equilibrium Unemployment and the Persistence of Business Cycles

Michael C. Burda
Humboldt University Berlin
Department of Economics
Spandauer Str.1
10178 Berlin
Germany and CEPR

Mark Weder*
Humboldt University Berlin
Department of Economics
Spandauer Str.1
10178 Berlin
Germany

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Abstract

This paper evaluates complementarities of labor market institutions and the business cycle in the context of a stochastic dynamic general equilibrium model economy. Matching between workers and vacancies with endogenous search intensity, Nash-bargained wages, payroll taxation, and differential support for unemployed labor in search and leisure are central aspects of the model. For plausible regions of the policy and institutional parameter space, the model exhibits more persistence than standard RBC models and often indeterminacy of rational expectations paths without increasing returns in

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production. Furthermore, labor market institutions act in a complementary fashion in generating these effects.

1 Introduction

The high level of unemployment in most European countries remains a difficult subject for economists. The number of candidate explanations has risen faster in recent years than the phenomenon itself. Since the publication of the OECD Job Report (OECD 1994), it is received wisdom that government policies – "institutions" – play a central role in this process. Here one includes unemployment insurance, collective bargaining mechanisms, social assistance, job protection and other labor market regulation, labor and capital taxation, and product market regulation. Problematic is the fact that these institutions existed in the 1960s: why are things so different now? For this reason, the more promising approaches have stressed interactions of institutions with exogenous events, or have invoked models with increasing returns to scale and multiple equilibria.¹ Recent work by Blanchard (1999) concludes that an important component of the variance in unemployment can be explained by interactions of institutions with shocks such as the oil price increases of the 1970s. The theoretical underpinning for these interactions is lacking, however.

In recent papers, Coe and Snower (1997) and Orzag and Snower (1998) have stressed the complementarity of labor market institutions in affecting unemployment. While these authors go far in identifying the sources of mutually reinforcing effects of institutions on the labor market, their analysis remains essentially static. The dynamics of such complementarities and their interactions with the rest of the macroeconomy are not well-understood. At the same time it is seldom stressed that rises in European unemployment have generally occurred at business cycle frequencies, making it a cyclical as well as a structural phenomenon. In a recent paper Prescott (1999) echoed the view that labor market institutions and the "rules of the game" may be essential to explaining phenomena like the Great Depression in the United States, the current bust in Japan or high unemployment in Europe. In any

¹For examples see Blanchard and Summers (1986a,b) Gilles St.-Paul (1998), and Ljungqvist and Sargent (1998).

case it would appear imperative to model unemployment as the outcome of an *equilibrium* process, given that the largest increases occurred at least two decades ago.

Our paper takes both the complementarities of labor market institutions and equilibrium dynamics seriously in a stochastic general equilibrium model. As the clearinghouse for the most important factor of production, it is reasonable to expect, as Prescott argues, that the functioning of the labor market will affect business cycle dynamics. Our paper takes this issue seriously, too, by giving up assumptions that labor markets are perfectly competitive or can costlessly replicate the social optimum, as in Merz (1995) and Andolfatto (1996). We incorporate a number of institutions which are suspected of influencing the steady state of economies, including the generosity of unemployment insurance, the subsidy of non-search unemployment (social welfare or unconditional unemployment assistance), the efficiency of job matching, labor taxation, and wage bargaining. In particular, we explicitly differentiate between unemployment insurance and social assistance for those who are unemployed and not searching. The provision of unemployment benefits is confronted with a moral hazard problem; it is difficult if not impossible to distinguish between those who search and those who do not. One key finding is that the "misclassification rate" of leisure as search unemployment - or the rate of moral hazard in another interpretation - plays a central role in determining the dynamic properties of the model. Finally, we study the model under both constant returns conditions usually employed in RBC analysis as well as under increasing returns to determine whether complementarities are operative between these aspects.

It is already known that taxation can induce multiple equilibria in static (Blanchard and Summers 1986) and indeterminacy in dynamic (Schmitt-Grohe and Uribe 1997) settings. By considering labor taxation, we explicitly allow for this interaction as well. The implication of indeterminacy under constant returns is to further increase the scope of "endogenous propagation mechanisms." Furthermore, our model allows us to analyze explicitly the consequences of a reform – admittedly only unexpected ones – as has been already done in the context of the Mortensen-Pissarides model (Millard and Mortensen 1997, Mortensen and Pissarides 1996). Isolating effects of labor market institutions can help in understanding the marked difference between US and UK economies on the one hand, and the continental economies on the other.

Intimately related to this issue is the nature of unemployment. As Lucas (1977, 1978, 1980), Pissarides (1990) and others have argued, the labelling of unemployment as "voluntary" or "involuntary" is ill-defined if not vacuous. The old notion of involuntary unemployment as a state in which workers are ready to work at some "going wage" (Keynes, 1936) does not do justice to the nature of the phenomenon. There are both involuntary and voluntary aspects of all unemployment; it is just as difficult to assess whether an unemployed worker who envies his employed colleagues is involuntary as it is to say that the employment of an archeology Ph.D. as a dishwasher is voluntary. This paper is agnostic as to the actual unemployment we observe, endorsing a concept of equilibrium unemployment which relies on matching frictions and search, but at the same time recognizes that the vast majority of unemployed do not choose this state.²

The central results of the paper can be summarized as follows. We find important regions of the parameter space are associated with both high output persistence as well as indeterminate dynamics ("indeterminacy", e.g. Benhabib and Farmer 1998). In particular, a higher "misclassification rate," the fraction of the rate at which leisure unemployment is treated as search unemployment, is also associated with indeterminacy. At the same time, holding the misclassification rate constant, higher replacement ratios can also generate indeterminacy. Our findings of complementarity extend also to the degree to which match surplus is shared as well as the extent of increasing returns in the economy.

The paper is organized as follows. In the following section, the sectors of an internally consistent dynamic general equilibrium model are described. In particular, the maximization problem of representative households and firms are used to derive aggregate demand and supply relationships and market clearing conditions for general equilibrium. In the third section, we study the equilibrium dynamics of the model economy, in particular the possibility of sunspot equilibria. This is followed by an analysis of the stochastic properties of the model's variables, which we compare with those of corresponding German time series. Section 5 presents some evidence on the marginal versus

²The variable unemployment is absent from most work in the RBC literature, which generally assumes clearing labor markets. Also, the near-exclusive use of perfectly competitive markets with aggregate Cobb-Douglas technology implies constant factor shares. Among the few exceptions that study the cyclical behavior of factor shares behavior see Cardia and Ambler (1993), Gomme and Greenwood (1995), and Feve and Langot (1996).

global effects of changing labor market institutions, and demonstrates that complementarity of labor market institutions extends *a fortiori* to a dynamic setting. Section 6 concludes.

2 Model

The model is a standard representative agent growth model of a closed economy. The household sector owns all inputs and rents their services to the firms. Firms employ a large number of intermediate goods to produce a homogeneous final good which is then sold to households to be consumed or invested as physical capital. There is uncertainty in the model, especially as regards the instantaneous employment of labor resources; following the literature, we assume the existence of complete contingent markets, so that agents can insure themselves against this idiosyncratic risk.³

2.1 Preferences

The economy consists of a large number of identical households of measure one.⁴ Every household has access to a complete set of frictionless assets markets. Preferences are defined over sequences of consumption c_t , and leisure \mathbf{l}_t :

$$E_0 \sum_{t=0}^{\infty} \beta^t U(c_t, \mathbf{l}_t) \quad \beta \in (0, 1). \quad (1)$$

β stands for the subjective discount rate. E_0 denotes the expectations operator conditional on time 0 information. Instantaneous utility is specialized to the functional form

$$U(c_t, \mathbf{l}_t) = \log c_t + \frac{A}{1 + \chi} \mathbf{l}_t^{1+\chi} \quad A > 0, \quad \chi \leq 0. \quad (2)$$

³See Merz (1995) and Andolfatto (1996). Clearly this is an approximation and not meant to imply that unemployment is harmless. Indeed the imperfect availability and moral hazard aspects of unemployment are likely to lead to co-insurance; even if unemployed were indifferent in equilibrium, resource costs of providing that insurance could be motivation alone for treating unemployment as a serious economic problem.

⁴Small letters indicate individual variables. Since households are identical (in equilibrium), we omit the identifying index.

The time endowment can be divided between leisure, employment l_t , and time engaged in search activity, s_t :

$$1_t + l_t + s_t = 1$$

The explicit modeling of time spent neither in work nor in leisure (i.e. non-market activities) is a novel aspect in the dynamic general equilibrium literature with search. Most existing models simply define search unemployment as the complement to time spent working, and capture the costliness of search in terms of lost output.⁵ Employment evolves according to

$$l_{t+1} = (1 - \delta_L)l_t + f_t s_t \quad \delta_L \in (0, 1]. \quad (3)$$

where f_t is the job finding rate per unit time expended, and δ_L represents an exogenous wastage of employment matches. In this model on-the-job search is ruled out.

Capital is accumulated by the households according to

$$k_{t+1} = (1 - \delta_K)k_t + i_t \quad \delta_K \in (0, 1]. \quad (4)$$

where k_t and i_t are the capital stock and investment expenditure respectively. Physical capital depreciates by δ_K per period.

2.2 Firms, Market Structure and Technology

Production of final goods takes place in two stages. Monopolistically competitive firms produce differentiated intermediate goods. These goods are welded together by a perfectly competitive industry to produce the final homogeneous output good, which will serve as numeraire in the economy.

2.2.1 Final Goods Sector

In the final goods sector, competitive firms have access to a technology that is linearly homogeneous in intermediate inputs $x_{i,t}$

$$Y_t = \left(\int_0^1 x_{i,t}^\sigma di \right)^{1/\sigma} \quad \sigma \in (0, 1). \quad (5)$$

⁵See for example Andolfatto (1996) or Merz (1995).

The number of intermediate goods is fixed and normalized to one. Then, the conditional cost function for final goods firms has the form

$$\mathbf{C}(Y_t, \mathbf{p}_{i,t}) = Y_t \left[\int_0^1 p_{i,t}^{\frac{\sigma}{\sigma-1}} di \right]^{\frac{\sigma-1}{\sigma}} \quad (6)$$

where $p_{i,t}$ is the price of input i . The representative final goods firm solves the static problem

$$\max_{Y_t} Y_t - \mathbf{C}(Y_t, \mathbf{p}_{i,t}). \quad (7)$$

2.2.2 Intermediate Goods Sector

In contrast to the final goods sector, output in the intermediate sector is supplied by a fixed set of monopolistically competitive firms. Each operates under internal increasing returns to scale with the production function

$$x_{i,t} = Z_t \left[k_{i,t}^\alpha l_{i,t}^{1-\alpha} \right]^\theta \quad \text{with } \alpha \in (0, 1), \text{ and } \theta \geq 1 \quad (8)$$

where $k_{i,t}$, $l_{i,t}$ are the firm's i input in capital and labor and θ is the scale parameter. Unless otherwise stated, total factor productivity evolves as a stationary stochastic process

$$Z_{t+1} = (1 - \rho_z)Z + \rho_z Z_t + z_{t+1} \quad Z \equiv 1, \rho_z \in [0, 1).$$

z_{t+1} is i.i.d. normal with mean zero and variance σ_z^2 . In choosing its optimal employment level, each monopolistic firm has to take into account current aggregate states and that it may take time to fill vacancies. Firms can post vacancies $v_{i,t}$ at cost a . Each firm chooses sequences of capital services to hire, and how much to invest in finding new workers by posting vacancies. In making these decisions, the firm must (implicitly, via the interest rate) take into account the households' savings sequences since their savings are the source of loanable funds necessary for firms' investments.

Each monopolistic firm i faces a constant elasticity of demand schedule for its output

$$x_{i,t}^D = p_{i,t}^{\frac{1}{\sigma-1}} Y_t \quad (9)$$

which can be derived from (6) via Shepard's Lemma.

2.3 Labor Market Institutions

2.3.1 Matching and Search in the Labor Market

One hallmark of the model we study is that it explicitly incorporates several significant deviations of labor markets from the Walrasian paradigm. In a model of equilibrium unemployment (see Pissarides 1990, Mortensen and Pissarides 1994), search and trade frictions preclude immediate wedding of production factors. Incremental changes in labor supply and the level of employment cannot take place instantaneously but require time and resources to match advertised vacancies by firms and search effort by agents. As a reaction to trade frictions, households must use part of their time endowment for labor market search activities. Similarly, firms post vacancies to signal workers their willingness to hire; these vacancies and the search activity of firms has resource costs which are either explicit (in the form of job placement agencies) or implicit (the opportunity cost for the firm engaged in search). Aggregate employment L_{t+1} , evolves according to⁶

$$L_{t+1} = (1 - \delta_L)L_t + M_t \quad \delta_L \in [0, 1] \quad (10)$$

where δ_L is an exogenous separation probability, M_t is the measure of job matches which occur in period t . The timing indicates a time-to-match lag. It has become standard to employ a functional form of Cobb-Douglas type⁷

$$M_t = V_t^\varrho S_t^{1-\varrho} \quad \varrho \in (0, 1).$$

Denote by V_t are the announced vacancies and S_t is the time spent by households in search (a crude measure of search efforts measured in units of time). This form derives its popularity from Blanchard and Diamond (1989) who report a reasonable fit with U.S. labor market data. There is a technical problem which has been noted by Den Haan, Ramey and Watson (1997) and motivates the following modification of the matching function:⁸

$$M_t = \frac{\Theta S_t V_t}{(S_t^{1/\varrho} + V_t^{1/\varrho})^\varrho} \quad \Theta > 0, \quad \varrho \in (-\infty, 1). \quad (11)$$

⁶Where possible to avoid confusion, we denote aggregate or equilibrium values by capital letters.

⁷See for example Pissarides (1990) or Merz (1995).

⁸Specifically, the Cobb-Douglas form does not guarantee matching probabilities between zero and one. In contrast, it is easy to verify that (11) satisfies the usual functional properties of a matching function while generating plausible matching probabilities.

The constant Θ is a scaling factor. Every agent and firm is defined to be small in relation to the economy so that actions do not affect aggregates and take matching rates as given. The rate that a given searching individual agent is matched with a vacant job during the unit interval – appearing in (3) – is given by

$$f_t = \frac{M_t}{S_t}. \quad (12)$$

For constant f , the mean duration of a completed unemployment spell is given by f^{-1} . Similarly, the rate at which vacancies are filled is defined as

$$q_t = \frac{M_t}{V_t}, \quad (13)$$

with mean steady-state vacancy duration given by $1/q$. As the respective transition rates depend on the aggregate number of the two types of traders, the matching process generates trading externalities.

Merz (1995), Andolfatto (1996), and Den Haan, Ramey and Watson (1997) also examine the role of search in dynamic general equilibrium model. The current paper differs from these because it explicitly admits the existence of relevant labor market institutions and abandons the assumptions that perfect competition obtains everywhere and that fluctuations are caused only by shocks to the economy’s fundamentals (as a rule, total factor productivity).

2.3.2 Payroll Taxes, Unemployment Insurance and Social Assistance

Our model economy possesses a simple government sector. Its role in the economy is to collect taxes and to redistribute them currently unemployed agents. Let τ_t be the payroll tax rate on labor income. We assume that the government runs a balanced budget. The government’s budget constraint is therefore

$$\tau_t w_t L_t = b S_t + \varepsilon b (1 - S_t - L_t) \quad (14)$$

where w_t is the wage rate and b is a transfer payment per unemployed agent who is engaged in search. Unemployed agents *not* engaged in search enjoy a transfer equal to εb with $\varepsilon \in [0, 1]$. The balanced budget restriction renders

the tax rate τ endogenous, while the unemployment insurance benefit b and ε are constant policy parameters.

It should be stressed that unemployment in the model has two forms: Time not spent working but spent in search for a new job, and leisure (time withheld from market activities). The government compensates both forms of unemployment in different ways. First an unemployment insurance type scheme compensates search S at constant b , will can be expressed as an constant fraction of the steady-state net wage. Second, non-search, non-market activity is subsidized by the social safety net as well: the parameter ε summarizes an important aspect of the "generosity" of the social safety net. In particular, it helps determines the gains from job search in unemployment, and represents the potential for a "poverty trap" in which agents are indifferent between work and the dole. A value of ε close to 1 reduces the net gains to search by increasing the value of nonmarket activity.

2.3.3 Wage Determination

In this section we model the wage bargaining process, which represents the second deviation from a standard labor market. Matches give rise to surplus which can be shared arbitrarily between paired agents and firms, so that the wage will generally deviate from marginal productivity remuneration characteristic of the neoclassical model. Wages in the present model are determined at the match level, as a Nash bargaining solution where the constant ξ can be interpreted as the bargaining strength of the firms. In particular, the wage satisfies the rule:⁹

$$w_t(1 - \tau_t) = (1 - \tau_t)(1 - \xi) \left[(1 - \alpha)\sigma\theta \frac{Y_t}{L_t} + \frac{a_t V_t}{S_t} \right] + \xi \left[\frac{A(1 - S_t - L_t)^\chi}{\lambda_t} + \varepsilon b \right] \quad (15)$$

where $\xi \in [0, 1]$.

According to (15), the net wage rate is a weighted average of the marginal product of labor net of advertising costs per number of unemployed agent and

⁹It can be derived from

$$\arg \max w_t = \left[(1 - \alpha)\sigma\theta \frac{Y_t}{L_t} + \frac{a_t V_t}{S_t} - w_t \right]^\xi \left[(1 - \tau_t)w_t - \frac{A(1 - L_t - S_t)^\chi}{\lambda_t} - \varepsilon b \right]^{1-\xi}$$

the disutility that arises from work corrected for forgone search costs. The expression $\frac{A(1-s_t-l_t)^\xi}{\lambda_t} + \epsilon b$ reflects the minimum compensation that workers require to work. In the extreme case $\xi \rightarrow 1$, the firm collects the maximum surplus and the wage rate reaches its allowable minimum. This sharing rule is similar in spirit to Merz (1995) and Andolfatto (1996), who show that for a particular values of ξ , this rule is equivalent to the optimal rule chosen by a social planner and the market solution and can be considered an optimal contract. This correspondence is only possible, however, in economies in which a one-to-one relationship exists between the market outcome and social (planner's) optimum. Andolfatto (1996) and Merz (1995) do not demonstrate convincingly why this should be the case, so that deviations from the optimum can be considered "labor market imperfections" which give excessive power either to labor or to management. Under a bargaining setup, it is easy to obtain suboptimal equilibria since the marginal product of labor is distorted away from its social opportunity cost, and agents do not necessarily internalize the effects of their presence in the market (Hosios 1990).

2.4 Optimal Behavior

2.4.1 Households

The household maximizes lifetime utility (1) by choosing a sequence of consumption, labor and physical capital subject to the constraints (3), (4) and the period-by-period resource restriction

$$c_t + i_t = (1 - \tau_t)w_t l_t + b s_t + r_t k_t + \epsilon b(1 - s_t - l_t) \quad (16)$$

where w_t and r_t are respectively the wage and the capital rental rate. We follow the standard procedure and assume that workers pool their incomes (and implicitly their unemployment) and make their policy decisions in a manner of a representative agent.¹⁰

¹⁰See, for example, Danthine and Donaldson (1995). To date no easily implementable algorithm is available allowing the modeller to track easily individual wealth profiles, unemployment durations, and other state variables; our procedure masks potential effects created by agent heterogeneity. Alternatively, one may think of each household being a family which receives income from having a fraction l_t of its members at work.

Denote the aggregate state of the economy by $\Omega_t \equiv \{K_t, L_t, Z_t\}$. The value function $v : \mathfrak{R}_+^2 \times \Omega \rightarrow \mathfrak{R}_+$ for the representative agent's dynamic programming problem satisfies the functional equation

$$v(k_t, l_t; \Omega_t) = \max_{c_t, s_t, l_{t+1}, k_{t+1}} U(c_t, l_t) + \beta E_t v(k_{t+1}, l_{t+1}; \Omega_{t+1}) \quad (17)$$

subject to (3), (4) (16) and given the aggregate laws of motion for Ω_t . The first order conditions are

$$\frac{1}{c_t} = \lambda_t \quad (18)$$

$$\lambda_t = \beta E_t \lambda_{t+1} [r_{t+1} + 1 - \delta] \quad (19)$$

$$\mu_t f_t = A(1 - s_t - l_t)^\chi - (1 - \varepsilon)\lambda_t b \quad (20)$$

$$\mu_t = \beta E_t [\lambda_{t+1} [(1 - \tau_{t+1})w_{t+1} - \varepsilon b] - A(1 - s_{t+1} - l_{t+1})^\chi + (1 - \delta_L)\mu_{t+1}] \quad (21)$$

where λ_t , and μ_t denote the Lagrangian multipliers associated with the capital (physical wealth) and employment constraints. The first two equations describe the optimal savings sequence. Equations (20) and (21) characterize the household's optimal search and labor supply policies. They imply that the household equalizes the marginal disutility of searching today to its expected payoff, which is given by the wage payments (in terms of consumption units) and minus disutility from working and plus the expected value of foregone search costs.

2.4.2 Firms

Because final good production is straightforward, we focus on the representative firm in the intermediate good sector. The problem of the representative firm can be defined as choosing values of vacancies, capital, and future employment such to maximize the expected sum of discounted profits, taking

the path of wages, interest rates, and intertemporal marginal rates of substitution as given. The households' optimal behavior implies an asset pricing kernel – the price at time t of a certain claim on period $t + 1$ consumption – equal to

$$\rho_{t+1} \equiv \beta \frac{\lambda_{t+1}}{\lambda_t} \quad (22)$$

which is the intertemporal marginal rate of substitution in consumption. It is assumed that ρ_{t+1} is the discount factor employed by firms and is taken by them as given.¹¹

Define the firm's value function $W: \mathfrak{R}_+ \times \Gamma \rightarrow \mathfrak{R}_+$. Assuming that a unique W exists, it can be characterized as the solution to the functional equation

$$W(l_t; \Omega_t) = \max_{v_{i,t}, k_{i,t+1}, l_{i,t+1}} p_{i,t} x_{i,t} - w_t l_{i,t} - r_t k_{i,t} - a v_{i,t} + E_t \rho_{t+1} W(l_{t+1}; \Omega_{t+1}) \quad (23)$$

subject to the production function (8) and the firm transition equation for employment

$$l_{i,t+1} = (1 - \delta_L) l_{i,t} + q_t v_{i,t}. \quad (24)$$

Profit maximization requires for each firm to set its capital, employment, and vacancy sequences such that

$$r_t = \alpha \sigma \theta p_{i,t} x_t k_t^{-1} \quad (25)$$

and

$$\frac{a}{q_t} = E_t \rho_{t+1} \left[(1 - \alpha) \sigma \theta p_{i,t} \frac{x_{i,t+1}}{l_{i,t+1}} + \frac{a(1 - \delta_L)}{q_{t+1}} - w_{t+1} \right]. \quad (26)$$

(25) indicates that firm hires capital up to the equality of the rental rate and the marginal product of capital. It is also optimal for the firm to advertise vacancies such that the marginal cost of posting an opening (per unit probability of filling the vacancy) is equal to expected profits plus the firm's costs of foregone search, conditional on that the job is filled (26).

¹¹In the absence of the representative agent or a complete contingent claims markets assumption, we would encounter difficulties in determining the firms' criterion function. See for example Radner (1974).

2.5 Symmetric Equilibrium

An equilibrium in this economy is a set of functions $(C_t, M_t, V_t, S_t, w_t, r_t, p_t, K_{t+1}, L_{t+1})$ defined on the aggregate state Ω_t which satisfy (i) profit and value maximization of firms, (ii) utility maximization of agents, and (iii) market clearing. The symmetry of the environment and market clearing implies that $K_t = k_t, L_t = l_t, C_t = c_t, V_t = v_t = v_{i,t}, \frac{M_t}{V_t} = q_t, \frac{M_t}{S_t} = f_t$. In equilibrium, zero profits in the final goods industry imply that the price of the final good must be equal to its unit costs. In symmetric equilibrium the equality

$$1 = \left[\int_0^1 p_{i,t}^{\frac{\sigma}{\sigma-1}} di \right]^{\frac{\sigma-1}{\sigma}}$$

requires that $p_{i,t} = p_t = 1$. Aggregate output is given by the reduced form

$$Y_t = Z_t [K_t^\alpha L_t^{1-\alpha}]^\theta. \quad (27)$$

The intermediate product firms' optimal policies are described by

$$r_t = \alpha \sigma \theta Y_t K_t^{-1} \quad (28)$$

and

$$a \frac{V_t}{M_t} = E_t \rho_{t+1} \left[(1 - \alpha) \sigma \theta \frac{Y_{t+1}}{L_{t+1}} + a(1 - \delta_L) \frac{V_{t+1}}{M_{t+1}} - w_{t+1} \right]. \quad (29)$$

Household behavior reduces to the following equations:

$$\frac{1}{C_t} = \lambda_t \quad (30)$$

$$\lambda_t = \beta E_t \lambda_{t+1} [r_{t+1} + 1 - \delta] \quad (31)$$

$$\mu_t \frac{M_t}{S_t} = A(1 - S_t - L_t)^\alpha - \lambda_t b + \varepsilon \lambda_t b \quad (32)$$

$$\mu_t = \beta E_t [\lambda_{t+1} [(1 - \tau_{t+1}) w_{t+1} - \varepsilon b] + (1 - \delta_L) \mu_{t+1} - A(1 - S_{t+1} - L_{t+1})^\alpha] \quad (33)$$

Aggregate constraints are given by

$$L_{t+1} = (1 - \delta_L)L_t + M_t \quad (34)$$

$$K_{t+1} = (1 - \delta_K)K_t + I_t \quad (35)$$

and

$$Y_t = C_t + I_t + a_t V_t. \quad (36)$$

Combined with the aggregate matching technology

$$M_t = \frac{\Theta S_t V_t}{(S_t^{1/\varrho} + V_t^{1/\varrho})^\varrho} \quad (37)$$

we have completed our description of the model. In the next section we study the dynamics of the loglinearized version of equations (27) to (37).

3 Dynamics

3.1 Steady state

In what follows we solve the model for steady state values, which can be shown to be unique. The capital-output ratio is determined implicitly by (31) and (28)

$$1 = \beta(\alpha\sigma\theta\frac{Y}{K} + 1 - \delta_K) \quad (38)$$

and the investment share is given by (35)

$$\frac{I}{Y} = \delta_K \frac{K}{Y}. \quad (39)$$

Steady state on the labor market requires that separations from jobs equal new matches from (34):

$$\delta_L L = M. \quad (40)$$

The government's budget constraint implies

$$\tau = \frac{b}{(1-\tau)w} \frac{1-\varepsilon}{L/S} + \frac{b}{(1-\tau)w} \frac{\varepsilon(1-L)}{L/S} \quad (41)$$

which pins down the tax rate τ once we have calibrated the steady state *net* replacement ratio $rr \equiv \frac{b}{(1-\tau)w}$, ε , S , and L . The remaining steady state conditions are

$$\mu \frac{M}{S} = A(1-S-L)^x - (1-\tau) \frac{b}{(1-\tau)w} \frac{w}{C} (1-\varepsilon) \quad (42)$$

$$\mu [1 - \beta(1 - \delta_L)] = \beta \left[(1-\tau) \frac{w}{C} - A(1-S-L)^x - (1-\tau) \frac{\varepsilon b}{(1-\tau)w} \frac{w}{C} \right] \quad (43)$$

$$\frac{aV}{Y} \frac{1}{M} [1 - \beta(1 - \delta_L)] = \beta \left[\frac{(1-\alpha)\sigma\theta}{L} - \frac{w}{C} \frac{C}{Y} \right] \quad (44)$$

$$\left[1 - \frac{\xi\varepsilon b}{(1-\tau)w} \right] (1-\tau) \frac{w}{C} \frac{C}{Y} = (1-\tau)(1-\xi) \left[(1-\alpha)\sigma\theta \frac{1}{L} + \frac{aV}{Y} \frac{1}{S} \right] + \xi \frac{C}{Y} A(1-S-L)^x \quad (45)$$

and

$$\frac{C}{Y} = 1 - \frac{I}{Y} - \frac{aV}{Y}. \quad (46)$$

This set of steady state conditions enables us to simultaneously find the unique values of aV/Y , A , μ , w/C , and C/Y . Finally, the matching technology is given by

$$M = \frac{\Theta SV}{(S^{1/\varrho} + V^{1/\varrho})^\varrho}. \quad (47)$$

The scale parameter Θ is calibrated such that S/V takes on a desired level consistent with the data.

3.2 Rational expectations solution

As is the case for most RBC models, the present model cannot be solved analytically. Following King, Plosser and Rebelo (1988), we loglinearize the model around its balanced growth path in the absence of shocks. Let us denote percentage deviations from the steady state by \widehat{X}_t , the rational expectations solution of the model reduces to the following stochastic matrix difference equation:

$$\begin{bmatrix} \widehat{S}_{t+1} \\ \widehat{\mu}_{t+1} \\ \widehat{\lambda}_{t+1} \\ \widehat{L}_{t+1} \\ \widehat{K}_{t+1} \\ \widehat{Z}_{t+1} \end{bmatrix} = \mathbf{M} \begin{bmatrix} \widehat{S}_t \\ \widehat{\mu}_t \\ \widehat{\lambda}_t \\ \widehat{L}_t \\ \widehat{K}_t \\ \widehat{Z}_t \end{bmatrix} + \mathbf{R} \begin{bmatrix} E_t \widehat{S}_{t+1} - \widehat{S}_{t+1} \\ E_t \widehat{\mu}_{t+1} - \widehat{\mu}_{t+1} \\ E_t \widehat{\lambda}_{t+1} - \widehat{\lambda}_{t+1} \\ 0 \\ 0 \\ E_t \widehat{Z}_{t+1} - \widehat{Z}_{t+1} \\ z_{t+1} \end{bmatrix} \quad (48)$$

where we note that search time, \widehat{S} , the shadow value of wealth, $\widehat{\lambda}$, and the shadow value of employment, $\widehat{\mu}$, are endogenous and nonpredetermined. The presence of imperfect competition and matching externalities implies that it is not possible to solve for the market equilibrium as the solution of the social planner. Similarly, and more importantly, the usual Arrow-Debreu welfare theorems cannot be invoked to rule out irregular rational expectations equilibria. In particular, if the matrix \mathbf{M} has more than three eigenvalues inside the unit circle, the rational expectations path is no longer unique. Such dynamic systems are said to be irregular. Indeterminacy in rational expectations of this type implies that equilibria are possible in which fluctuations in economic activity are driven by arbitrary and self-fulfilling changes in people's expectations. It should be stressed that such sunspot equilibria are not based on agent irrationality - under the circumstances it is perfectly rational to follow such nonfundamental signals. Rational expectations business cycle models with indeterminacy represent a workable equilibrium interpretation of Keynes' animal spirits hypothesis.¹²

¹²See Farmer (1993), Farmer and Guo (1994) or Benhabib and Farmer (1998) for extensive discussions of these issues.

3.3 Calibration

In this subsection we describe the parametric specification of our model and assign parameter values such that the long run properties of our model economy correspond to the growth path of postwar Germany. This calibration methodology is now common procedure in modern dynamic general equilibrium theory. The fundamental period in the model is the quarter, so we will compare our model economy performance to quarterly German time series.

In the absence of stochastic disturbances, the model is in its steady state. In steady state, we assume that the agents spend 20 percent of their time endowment working. We set the rate of unemployment equal to 7.5 percent which implies a value for S of 0.016; this implies that unemployed agents spend about 20 minutes per day (on average) in search. The parameter δ_L which is also the ratio of unemployment rate to the employment rate, is set equal 0.081 as in Merz (1995). We assume $\varrho = 0.78$ as in den Haan, Ramey and Watson (1998). Labor and firms are assigned equal bargaining strength so that $\xi = 0.50$. We set the steady state tax rate τ such that the unemployed agents receive 50 percent of the steady state net wage, which is realistic for Germany. Finally, the absence of strong evidence of significant pure profits in the empirical literature motivates us to set $\theta = 1/\sigma$. The parameters (α, β , and δ_K) are standard in RBC models (see for example Cooley and Prescott, 1995).

Table 1 summarizes the benchmark model. Remaining parameters will be calibrated in the next section. Depending on the particular values taken by those parameters, the implied consumption share is roughly 75 percent and the fraction aV/Y assumes very small positive values (less than one percent of output).

TABLE 1: Calibration values for the model economy	
Parameter	Calibrated Value
α	0.30
β	0.99
θ	$1/\sigma$
S	0.016
ξ	0.50
δ_K	0.025
δ_H	0.0125
ε	0.30
ϱ	0.78
L	0.20

3.3.1 Indeterminacy

We have fixed all parameters *a priori* except the degree of increasing returns (θ), the replacement rate ($rr \equiv b/(1-\tau)w$), the welfare generosity parameter (ε) and the labor supply elasticity ($-\chi^{-1}$). Our strategy is now to look at the behavior of the economy for various combinations of these parameters. In particular, we are interested in those combinations which contribute to output and employment persistence (eigenvalues near the unit circle) and yield irregular equilibria (more than three eigenvalues inside the unit circle).

We first consider combinations of θ and the slope of the labor supply which yield indeterminacy of rational expectations paths. To focus attention on a benchmark case with the least institutional detail, we set both rr and ε – and thereby taxes – equal to zero.¹³ At one extreme, the minimum increasing returns required to obtain indeterminacy is 1.51 in the "Hansen" (Hansen 1985) case of infinitely elastic aggregate labor supply, and is slightly higher than in the Benhabib and Farmer (1994) model. At the other extreme, the lower bound on increasing returns necessary for indeterminacy rises at low labor supply elasticities.¹⁴ Again, this pattern is similar to models with a

¹³To facilitate comparison with Merz (1995) and Andolfatto (1995), we consider in this case a Cobb-Douglas matching function with an elasticity of matches with respect to vacancies of 0.4, an estimate found in Blanchard and Diamond (1989)

¹⁴It is noteworthy, however, that the absolute value of eigenvalues of the matrix \mathbf{M} do not approach infinity at the bifurcation point as in other indeterminacy models but rather

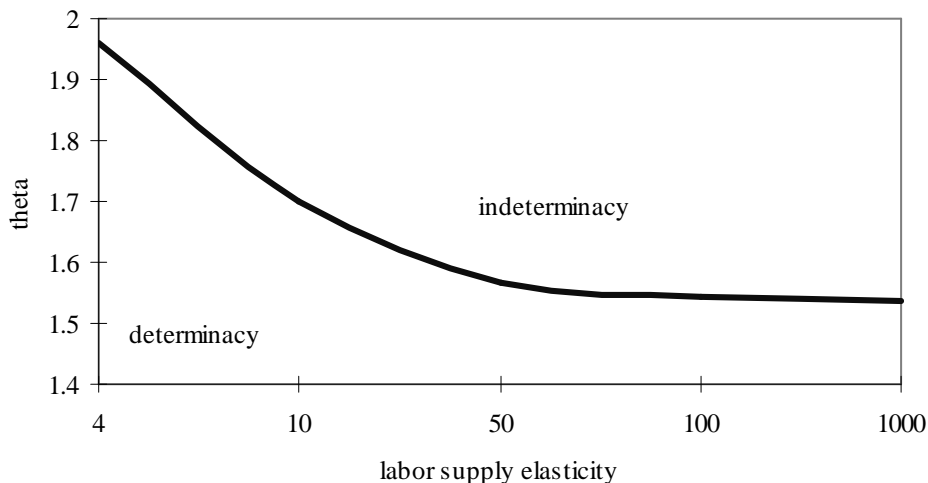


Figure 1: Indeterminacy regions in $(-\chi^{-1}, \theta)$ space

Walrasian labor market. We conclude that in this parametrization, dynamic equilibria with indeterminacy can only obtain at implausibly high returns to scale.

In Figure 2 we take a different tack, assessing combinations of rr and ε while assuming constant returns to scale and $\chi = 0$. Once tax distortions are introduced, indeterminacy is more likely to obtain.¹⁵ In fact, if the net replacement ratio exceeds roughly 50 percent (which is the case for unemployment compensation in Germany and most Western European countries) increasing returns in production are no longer necessary to induce the indeterminacy result. If we allow for social security payments ($\epsilon > 0$), the model exhibits indeterminacy at all reasonable calibrations for European economies. A numerical example that implies indeterminacy at constant returns underscores the plausibility of our argument: assuming German values for the gross

pass through the unit circle. Therefore, the values that we present here indicate the "sure" indeterminacy region only. We have not explored the possibility of other cycles that may arise in the neighborhood of θ^{\min} .

¹⁵See Schmitt-Grohe and Uribe (1997).

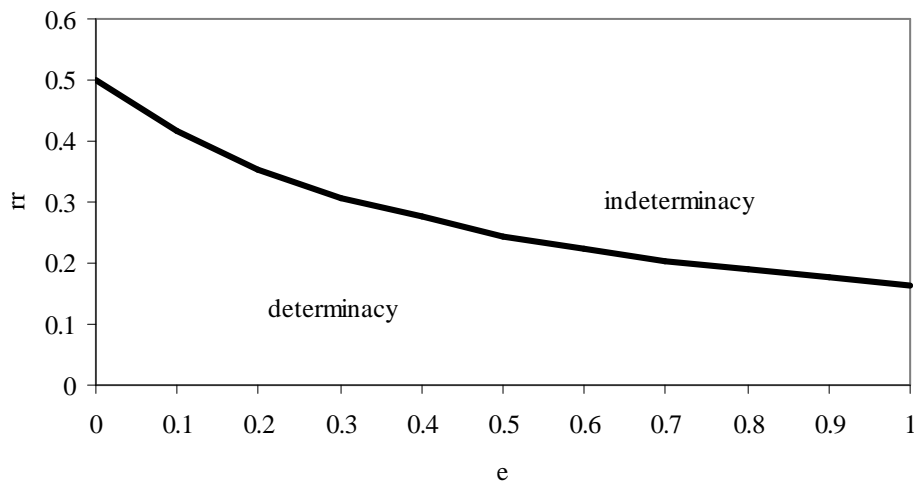


Figure 2: Indeterminacy regions in (rr, ϵ) space

quarterly wage income of 7500 Euro, a replacement rate of 58 percent, and ϵ equal to 0.30, the calibration implies that the tax rate is 27 percent and the social security payments are 954 Euro per quarter, plausible values for Germany's current welfare system.

The economic intuition for indeterminacy is straightforward. Suppose that agents expect the future real return to labor (and capital) to be high: they start investing and searching today to realize these returns tomorrow. Under normal conditions of decreasing returns, a higher level of employment implies a lower future wage rate and thus cannot be a rationally expected equilibrium since the wage must increase rather than decrease. That is exactly where increasing returns enter the picture. Future output and marginal products must rise in order to validate expectations of a higher marginal product. Any given labor (and capital) input generates a larger marginal product and the initial optimistic belief of higher returns is self-fulfilling. This can only happen if increasing returns in production allow it, or when taxes on labor income are *countercyclical*. But this is exactly what the balanced budget requires. Since increased employment implies a

lower equilibrium tax rate, the after-tax return to labor can be increasing with labor even in the absence of increasing returns to scale. Expectations on higher returns can again be self-fulfilling. Furthermore, the reduced degree of distortions shifts out the *effective* production possibility frontier, thus generating a wealth effect that spurs additional spending. A complementary effect arises from the additional fiscal relief due to lower take-up of welfare in good times.

We suspect that the model's (fiscal and productive) increasing returns are only partly responsible for the result and that the model's pseudo two-sector structure – induced by the delay between increased search of firms and workers and increased employment – is also responsible.¹⁶ That is, an increase in search activity need not coincide with employment reductions. Rather, additional resources can be drawn out of leisure. The equilibrium return schedules to labor and to search shift as a result of the agents composition of time allocation. This behavior will also be important in explaining the model's output persistence.

4 Moments

4.1 Population moments

In Table 1 and 2 we present business cycle statistics in the form of population moments for macroeconomic variables from the U.S. and West Germany. We choose Hodrick-Prescott filtering as our lens for viewing the data. Like many OECD countries, one finds a confirmation of the usual business cycle facts: consumption is (slightly) smoother than GDP whereas investment is much more volatile than GDP. Business cycle persistence refers to the fact that when the growth rate of undetrended output is above average, it tends to remain high for a few quarters. One measure of persistence is the autocorrelation statistic; if the data follow a random walk, the autocorrelation is zero; if there is strong mean reversion in the levels, the first differenced data would evidence negative autocorrelation. For U.S. and German GDP data, the autocorrelation statistic displays positive serial correlation positive for lags one to three. The U.S. economy display similar statistics. The only important

¹⁶One might think of two separate technologies with output which is either physical goods or job matches.

differences between the two economies appear to be that the U.S. cycle is less persistent than Germany's, and that labor lags the cycle in Germany rather than being coincident.

Variable x	Rel. Volatility	Correlation of Output (real GDP) with						
		x(t-3)	x(t-2)	x(t-1)	x(t)	x(t+1)	x(t+2)	x(t+3)
Output	1.00	0.38	0.63	0.85	1.00	0.85	0.63	0.38
Consumption	0.50	0.55	0.68	0.78	0.77	0.64	0.47	0.27
Investment	3.10	0.43	0.63	0.82	0.90	0.81	0.60	0.35
Labor	0.97	0.14	0.39	0.67	0.88	0.91	0.80	0.63
Wage share	0.45	-0.44	-0.53	-0.51	-0.46	-0.13	0.13	0.32
Unemployment	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Vacancies	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Output growth	1.00	0.03	0.22	0.37	1.00	0.37	0.22	0.03

Source: Cooley (1995) and Christiano and Todd (1996) from which we took the output growth figures (1947:I-1995:I).

Variable x	Rel. Volatility	Correlation of Output (real GDP) with						
		x(t-3)	x(t-2)	x(t-1)	x(t)	x(t+1)	x(t+2)	x(t+3)
Output	1.00	0.60	0.78	0.89	1.00	0.89	0.78	0.60
Consumption	0.66	0.62	0.75	0.85	0.94	0.92	0.73	0.60
Investment	1.98	0.55	0.74	0.86	0.96	0.89	0.79	0.65
Labor	0.51	0.09	0.28	0.48	0.65	0.78	0.84	0.85
Wage share	0.57	-0.54	-0.53	-0.46	-0.36	-0.18	0.02	0.21
Unemployment	9.49	-0.30	-0.48	-0.69	-0.78	-0.85	-0.86	-0.80
Vacancies	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Output growth	1.00	0.28	0.21	0.35	1.00	0.35	0.21	0.28

Variable definitions: Private Final Consumption Expenditures (C), I=Fixed Capital Formation (I), Output =C+I

Total Employment, Standardized Unemployment Rate. All variables (except wage share and unemployment) have been logged and detrended by applying the Hodrick-Prescott filter. All relevant variables are measured in 1991 DM terms.

Source of Data: OECD National Accounts and IMF Economic Indicators, Statistisches Bundesamt (output growth).

4.2 Model Moments

4.2.1 Search Model with Determinate Solution Paths (RBC)

We begin by exploring the implications of an economy *not* subject to any imperfections except for labor market search. In particular, we consider an economy with output elasticity of capital (α) equal to 0.36, $\varepsilon = rr = 0$, constant returns ($\theta = 1$), equal bargaining power, $\xi = 0.5$, and $\chi = -1$). This economy is determinate and the calibration is summarized at the top of Table 4. It is well-known that when productivity shocks are serially uncorrelated, the model is largely incapable of replicating business cycle behavior, and we abstain from harping on this point. When subject to persistent technology shocks ($\rho_z = 0.95$), the model generates the following business cycles:

Variable x	Rel. Volatility	Correlation of Output with						
		x(t-3)	x(t-2)	x(t-1)	x(t)	x(t+1)	x(t+2)	x(t+3)
Output	1.00	0.30	0.53	0.81	1.00	0.81	0.53	0.30
Consumption	0.34	0.10	0.36	0.67	0.91	0.79	0.66	0.55
Investment	3.57	0.36	0.57	0.82	0.99	0.78	0.47	0.21
Labor	0.37	0.20	0.45	0.63	0.84	0.91	0.53	0.24
Wage Share	0.11	-0.22	-0.28	-0.32	-0.16	0.41	0.33	0.28
Unemployment	0.39	-0.06	-0.10	-0.17	-0.36	-0.77	-0.48	-0.26
Vacancies	4.55	0.25	0.31	0.35	0.18	-0.36	-0.31	-0.27
Output growth	1.00	-0.06	-0.07	0.26	1.00	0.26	-0.07	-0.06

Statistics are based on 2000 artificial realizations of the model.

As already established by Andolfatto (1996) and Merz (1995), the RBC model with search is able to replicate major stylized business cycle facts, in both qualitative terms and as regards relative volatilities and comovements of output with other macroeconomic aggregates. Moreover, the persistence of output and output growth is significantly greater than in standard RBC models with Walrasian labor markets. Ostensibly, sluggishness resulting from labor market matching generates positive autocorrelations (at lag one). Another unusual feature is that labor lags the cycle by one quarter as in the U.S. economy. Unlike standard RBC models, the wage share is nonconstant and follows a countercyclical pattern as reported in Tables 2 and 3. In addition, it is noteworthy that our model generates a slight phase shift in the wage

share which is the same shift as the one found in the data, a fact which is not replicated by Merz's (1995) RBC model.

Before concluding the discussion of the conventional RBC model (with determinate equilibrium paths), we display the effects that labor and product market imperfections can have on output persistence in Table 5. Recall that this discussion was absent from Merz (1995), Andolfatto (1996) and den Haan et al. (1997) as labor market institutions were inadmissible in their analyses. Starting from the baseline calibration (Table 4), we alter parameters rr , ϵ , and θ and report the first order autocorrelation of output growth induced by that parameter variations. While the table gives only a cursory glimpse of the effect and a more detailed analysis will follow, it is safe to conclude that these imperfections generally increase output persistence in our model.

TABLE 5 AUTOCORRELATIONS OF OUTPUT			
baseline	$rr = 0.25$	$rr = 0.25$ $\epsilon = 0.25$	$\theta = 1.10$
0.26	0.42	0.40	0.45

4.2.2 Search Model with Indeterminacy deriving from Institutions

We now turn to model economies with indeterminacy induced by institutional features, modest increasing returns, or both. We assume constant returns in production and some imperfections due to the government intervention. We first consider a model in which indeterminacy arises due to institutions only. To focus discussion on the innovations in this paper, we consider $\epsilon = 0.3$, $\xi = 0.4$, and $rr = 0.5$ with otherwise standard features: $\chi = 0$ (Hansen 1995), $\theta = 0$ (constant returns), and $\alpha = 0.3$. The model is driven by white noise sunspot activity only. The resulting economy can be compactly described in Table 6.

Variable x	Rel. Volatility	Correlation of Output with						
		x(t-3)	x(t-2)	x(t-1)	x(t)	x(t+1)	x(t+2)	x(t+3)
Output	1.00	0.11	0.41	0.78	1.00	0.78	0.41	0.11
Consumption	0.16	-0.24	0.05	0.37	0.55	0.66	0.67	0.62
Investment	3.89	0.06	0.31	0.67	0.98	0.79	0.41	0.09
Labor	1.58	0.15	0.45	0.80	0.99	0.74	0.36	0.04
Wage Share	0.15	0.37	0.45	0.28	-0.25	-0.11	-0.07	-0.05
Unemployment	1.64	0.03	-0.19	-0.56	-0.95	-0.82	-0.46	-0.14
Vacancies	12.73	0.59	0.40	-0.26	-0.50	-0.44	-0.30	-0.16
Output growth	1.00	-0.22	-0.08	0.34	1.00	0.34	-0.08	-0.22

The first remarkable qualitative result to be reported is that consumption is procyclical without any need of scale economies or technology shocks. This can be regarded as an improvement of indeterminacy models with low (here constant) returns to scale.¹⁷ The economic intuition for this result is as follows. First, with the presence of fiscal increasing returns, distortions are countercyclical and thereby shift the *effective* production possibility frontier. Secondly, the resources that the economy allocates towards vacancies - less than one percent of output - are countercyclical. In a sense, firms' search is the absorbing sector: the economy has a two-sector character. Further, output is persistent as evinced by the significant positive autocorrelation of output growth. The wage share and the rate of unemployment are countercyclical. In contrast to most models of this genre, labor input is too volatile.

A couple of problems with the sunspot variant should be noted. First, the wage share displays the wrong phase shift: it peaks a few quarters before output rather than lagging it. Second and more significantly, while vacancies lead the cycle, their contemporaneous correlation with output is at odds with what is observed in actual economies. The intuition for this result seems to be the increasing unattractiveness of posting vacancies as the economy approaches the peak in the cycle. Recall that the attractiveness of vacancies can be derived from their effectiveness in generating employment matches. As unemployment in the form of search and leisure declines, the return from vacancies declines as well. Consequently, only the rationally expected future

¹⁷It should be noted that even with significant increasing returns, the Benhabib and Farmer (1996) two-sector economy displays a negative correlation of consumption with output at business cycle frequencies.

improving returns from employment can rationalize posting more vacancies. Clearly, this points to a missing feature in the model, either the need for shifts in the production function (due either to technology shocks or to increasing returns) or to heterogeneity in labor markets which could explain on-the-job search and job ladder phenomenon. The latter would be an interesting aspect as it is well-known that mobility and vacancies are highly procyclical and that reporting of vacancies is countercyclical. Yet it is not clear that this feature hinders our ability to account for the lion's share of labor market facts.

4.2.3 Search Model with Indeterminacy Deriving from Increasing Returns in Production

The third case we consider assumes increasing returns to scale and market power of firms in the intermediate sector. We set $\theta = 1/\sigma = 1.2$ which is at the upper bound of recent studies for the U.S. economy and appears even more plausible for Europe.¹⁸ Table 7 reports the statistics associated with the increasing returns model. As with the previous example, we continue to suppress technological shocks and assume sunspot shocks only.

Variable x	Rel. Volatility	Correlation of Output with						
		x(t-3)	x(t-2)	x(t-1)	x(t)	x(t+1)	x(t+2)	x(t+3)
Output	1.00	0.41	0.62	0.85	1.00	0.85	0.62	0.41
Consumption	0.33	0.41	0.68	0.88	0.79	0.71	0.61	0.51
Investment	4.01	0.03	0.46	0.68	0.96	0.83	0.59	0.36
Labor	1.19	0.46	0.67	0.87	0.99	0.81	0.55	0.32
Wage Share	0.15	0.28	0.30	0.16	-0.33	-0.21	-0.19	-0.15
Unemployment	1.19	-0.30	-0.46	-0.68	-0.96	-0.84	-0.61	-0.38
Vacancies	8.09	0.43	0.48	0.35	-0.19	-0.36	-0.35	-0.30
Output growth	1.00	0.02	0.08	0.35	1.00	0.35	0.08	0.02

This variant can replicate a business cycle characteristics slightly better than the first: consumption becomes more volatile and more procyclical. Similarly to (U.S.) data, it is slightly leading the cycle. When compared to

¹⁸See for example Basu and Fernald (1997), and Röger (1999).

the model version with constant returns, vacancies are leading the cycle and are only mildly negatively correlated at lag zero.

We conclude the discussion of cyclical model behavior with a version of the model that incorporates both sunspot and technology shocks. Technology follows an autocorrelated pattern: $\rho_z = 0.95$. The rest of the calibration is the same as in the last model version with increasing returns. In doing so, we stress the indeterminacy character of model that permits the introduction of nonfundamental disturbances. Both shock sequences are perfectly correlated, which lends itself to the interpretation of sunspots as "technology-induced exuberance" of investors.

Variable x	Rel. Volatility	Correlation of Output with						
		x(t-3)	x(t-2)	x(t-1)	x(t)	x(t+1)	x(t+2)	x(t+3)
Output	1.00	0.37	0.58	0.83	1.00	0.83	0.58	0.37
Consumption	0.23	0.21	0.48	0.69	0.70	0.72	0.70	0.65
Investment	4.35	0.30	0.47	0.72	0.98	0.81	0.54	0.32
Labor	1.30	0.47	0.68	0.89	0.98	0.77	0.49	0.27
Wage Share	0.25	0.31	0.33	0.11	-0.37	-0.19	-0.18	-0.14
Unemployment	1.26	-0.31	-0.48	-0.73	-0.98	-0.83	-0.56	-0.33
Vacancies	8.46	0.46	0.50	0.31	-0.27	-0.41	-0.36	-0.30
Output growth	1.00	-0.01	0.02	0.29	1.00	0.29	0.02	-0.01

While most stylized facts are replicated, the introduction of technology shocks hardly changes the qualitative results of the simulation, so that the marginal value of exogenous shifts to the production function is not entirely evident in this case.

In summarizing our findings, we can state that our model is capable of reproducing most stylized business cycle facts. This is possible without the need to assume technology shocks as the main driving force of the business cycle. Along a several dimensions, the model fares better than the standard RBC approach with Walrasian markets. In particular, the introduction of institutions induces additional output persistence which is much closer to the data.

5 Complementarities in Policy Interventions: Partial versus Global Reforms

In a widely noted paper, Coe and Snower (1997) discuss the inefficacy of partial labor market reforms which marginally alter only a subspace of existing labor market interventions without addressing interactions the institutions might have on incentives. This *complementarity* of policy reform means, for example, that a piecemeal reduction of unemployments benefit will deliver only modest labor market effects, if taxation, union bargaining, or the social welfare system are not reformed at the same time. In this section we argue that in a well-articulated dynamic general equilibrium model, this conclusion extends to the *persistence* of output as well. It might therefore explain the differential persistence in continental European output data relative to the US and other Anglo-American economies, which is evident in comparison of Tables 2 and 3.

Let us now return to Figure 2 which shows combinations of the replacement rate rr and welfare generosity ε that yield either determinacy or indeterminacy. The latter is obviously connected to an economic system that is more unstable *ceteris paribus* due to nonfundamental disturbances. We saw that if both government measures are driven to zero, the economy is determinate unless we assume a large degree of market power as was shown in Figure 1. Thus, a global systematic change in government policies can reduce economic instability as sunspot equilibria become less likely. However, this must not be the case if reforms are partial only. In particular, if the replacement ratio exceeds 50 percent (which is lower than German unemployment compensation and that of other Western European countries), a total reduction of social security payments does not alter the qualitative behavior of the economy. The model is still indeterminate and potentially subject to nonfundamental shocks. Equivalently, if the "misclassification rate" (or generosity parameter) ε is large, a stronger cutback in unemployment compensation is needed to rule out sunspot equilibria. Overall, our results suggest that when drawing preliminary policy implications from our model, a more global reform of the social welfare system would be more appropriate than small, piecemeal changes to produce a less volatile macroeconomy.

TABLE 10 UNEMPLOYMENT PERSISTENCE					
<i>rrate</i>	ε	$AR(1)$	<i>rrate</i>	ε	$AR(1)$
0.5	0.3	0.19	0.5	0.25	0.36
0.45	0.3	0.52	0.5	0.2	0.40
0.4	0.3	0.75	0.5	0.1	0.37
0.35	0.3	determinacy	0.5	0	determinacy

6 Conclusion

A significant failure of a number of models in quantitative economic theory is their inability to replicate the key aspect that makes "business cycles all alike," namely the typical persistent, cyclical shape observable in macroeconomic variables. In the frequency domain, this persistence is evidenced in hump-shaped spectra with a peak at frequencies in the interval $[2\pi/28, 2\pi/16]$ in quarterly data. Despite rigorous microfoundations, most models are unable to reproduce this key regularity without *ad hoc* serial correlation in innovations to total factor productivity, which seems as arbitrary as the lack of microfoundations that equilibrium business cycle models was designed to correct (Watson 1993, Soderlind 1994, Cogley and Nason 1995, Rotemberg and Woodford 1996). This failure has made further progress in dynamic general equilibrium modelling difficult and has impeded acceptance within a large segment of the economics profession.

In this paper we show that significant progress is possible on this front by considering explicit imperfections in the labor market as well as their *complementarity*. Although the labor market is the economy's "boiler room," accounting for two-thirds of all factor payment transactions, the quality and demand for what is traded is in fact remarkably heterogeneous and trade highly decentralized. Actions of agents may exert external effects on the evolution of the aggregate quantity of labor transacted. Finally, the wage is an instrument of distribution of surplus as well as an indicator of labor productivity. The size of the surplus as well as its division may be influenced by non-market factors, primarily labor market institutions. As a result, factor remuneration may deviate significantly from neoclassical marginal cost principles, at least in the short to medium term. Surprisingly, such imperfections and their interaction only occupy a subsidiary role in the literature

on dynamic equilibrium macromodels.¹⁹

In the tradition of quantitative economic theory (see Cooley and Prescott 1995 for an overview), this paper has evaluated the role of labor markets and the cycle in terms of realizations of a stochastic, dynamic general equilibrium model economy. In this methodology, sparsely parametrized models with internally consistent microeconomic foundations are judged by their ability to replicate key statistical features of the data. The importance of labor markets and especially labor market institutions for the business cycle motivates us to look at two aspects in particular. First, the non-Walrasian nature of labor markets is captured by a matching process which implies that time and resources are necessary to link workers and jobs. Second, the division of the surplus of matches leads to persistent, but not permanent deviations of marginal productivity from factor remuneration. Varying allowing the division of surplus to vary over socially suboptimal values is supposed to stand in for "labor market institutions" which enhance the bargaining power of labor or capital.²⁰ Third, we admitted explicitly the possibility of endogenous search, introducing a third use of time in addition to work and leisure. Finally a government is modelled to allow for potential interactions with the tax system.

The introduction of labor market imperfections, wage bargaining, and endogenous search, combine *and interact* with market power in product markets and a distortionary government to create persistence in the simulated time series. An important finding is that, for a plausible region of the parameter space, the model exhibits strong persistence and nonuniqueness of rational expectations equilibria. Furthermore, it is no longer necessary to impose increasing returns in production to induce this result. In recent years a number of researchers have formulated models with sunspot equilibria and self-fulfilling prophecies as an alternative to the technology-driven, real business cycle literature (Farmer and Guo (1994), Benhabib and Farmer (1996, 1999)). This paper contributes to this literature by bringing together both

¹⁹Some examples of models in the tradition of quantitative economic theory which admit non-standard labor markets include Danthine and Donaldson (1995), Merz (1995), Andolfatto (1996), Gali (1994), Boldrin and Horvath (1995).

²⁰Merz (1995) and Andolfatto (1996) have both stressed persistence effects which can arise in business cycles models with search in labor markets. Our model differs from their in that we do not assume that the decentralized labor market attains the social optimum.

sunspot and technology-driven business cycle models with a non-Walrasian labor market. In particular, it is the first attempt within the indeterminacy literature that departs from the assumption of perfect labor markets. It is shown that with these simple changes from the common Real Business Cycle (RBC) models, the model can reproduce a number of key stylized facts of the business cycle. Some of these elusive stylized facts include the persistence and countercyclical behavior of the labor share and unemployment as well as output and its components.

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7 Appendix: The Loglinearized Model

$$\widehat{Y}_t = \widehat{Z}_t + \alpha\theta\widehat{K}_t + (1 - \alpha)\theta\widehat{L}_t \quad (49)$$

$$\widehat{r}_t = \widehat{Y}_t - \widehat{K}_t \quad (50)$$

$$\begin{aligned} \frac{aV}{Y} \frac{1}{M} [\widehat{V}_t - \widehat{M}_t] &= \beta \left[\frac{(1 - \alpha)\sigma\theta}{L} - \frac{w}{C} \frac{C}{Y} + \frac{aV}{Y} \frac{1 - \delta_L}{M} \right] \widehat{\rho}_{t+1} \\ + \beta \frac{(1 - \alpha)\sigma\theta}{L} [\widehat{Y}_{t+1} - \widehat{L}_{t+1}] &- \beta \frac{w}{C} \frac{C}{Y} \widehat{w}_{t+1} + \beta \frac{aV}{Y} \frac{1 - \delta_L}{M} [\widehat{V}_{t+1} - \widehat{M}_{t+1}] \end{aligned} \quad (51)$$

with

$$\widehat{\rho}_t = \widehat{\lambda}_{t+1} - \widehat{\lambda}_t \quad (52)$$

$$\widehat{C}_t = -\widehat{\lambda}_t \quad (53)$$

$$\widehat{\lambda}_t = E_t \widehat{\lambda}_{t+1} + \beta r E_t \widehat{r}_{t+1} \quad (54)$$

$$\begin{aligned} \mu \frac{M}{S} [\widehat{\mu}_t + \widehat{M}_t - \widehat{S}_t] &+ \chi A (1 - S - L)^{\chi-1} [S \widehat{S}_t + L \widehat{L}_t] \\ &= -(1 - \tau) \frac{b}{(1 - \tau)w} \frac{w}{C} \widehat{\lambda}_t + (1 - \tau) \frac{\varepsilon b}{(1 - \tau)w} \frac{w}{C} \widehat{\lambda}_t \end{aligned} \quad (55)$$

and

$$\begin{aligned} \mu \widehat{\mu}_t &= \beta (1 - \tau) \frac{w}{C} \left[\widehat{w}_{t+1} + \widehat{\lambda}_{t+1} - \frac{\tau}{1 - \tau} \widehat{\tau}_{t+1} \right] \\ + \beta (1 - \delta_L) \mu \widehat{\mu}_{t+1} &- \chi \beta A (1 - S - L)^{\chi-1} [S \widehat{S}_{t+1} + L \widehat{L}_{t+1}] \\ &- \beta (1 - \tau) \frac{\varepsilon b}{(1 - \tau)w} \frac{w}{C} \widehat{\lambda}_{t+1} \end{aligned} \quad (56)$$

Aggregate constraints are given by

$$\widehat{L}_{t+1} = (1 - \delta_L)\widehat{L}_t + \delta_L\widehat{M}_t \quad (57)$$

$$\widehat{K}_{t+1} = (1 - \delta_K)\widehat{K}_t + \delta_K\widehat{I}_t \quad (58)$$

and

$$\widehat{Y}_t = \frac{C}{Y}\widehat{C}_t + \frac{I}{Y}\widehat{I}_t + \frac{aV}{Y}\widehat{V}_t. \quad (59)$$

And the bargaining equation:

$$\begin{aligned} & \left[\xi S \frac{C}{Y} + \xi S \frac{C}{Y} A\chi(1 - L - S)^{x-1} + (1 - \tau)(1 - \xi) \frac{aV}{Y} S^{-1} \right] \widehat{S}_t \quad (60) \\ & + \left[\xi L \frac{C}{Y} A\chi(1 - L - S)^{x-1} - (1 - \tau)(1 - \xi)(1 - \alpha)\sigma\theta L^{-1} \right] \widehat{L}_t \\ & = \xi \frac{C}{Y} [A(1 - L - S)^x - S] \widehat{C}_t + (1 - \tau)(1 - \xi)(1 - \alpha)\sigma\theta L^{-1} \widehat{Y}_t \\ & \quad - \frac{w}{C} \frac{C}{Y} (1 - \tau) \widehat{w}_t + (1 - \tau)(1 - \xi) \frac{aV}{Y} S^{-1} \widehat{V}_t \\ & \quad \left[\frac{w}{C} \frac{C}{Y} \tau - \tau(1 - \xi) \left((1 - \alpha)\sigma\theta L^{-1} + \frac{aV}{Y} S^{-1} \right) \right] \widehat{\tau}_t \end{aligned}$$

The two alternative matching functions are linearized as

$$\widehat{M}_t = \varrho \widehat{V}_t + (1 - \varrho) \widehat{S}_t \quad (61)$$

and

$$\widehat{M}_t = \left(1 - \frac{V^{1/\varrho}}{(S^{1/\varrho} + V^{1/\varrho})} \right) \widehat{V}_t + \left(1 - \frac{S^{1/\varrho}}{(S^{1/\varrho} + V^{1/\varrho})} \right) \widehat{S}_t \quad (62)$$