On the European Unemployment Puzzle: Matching Unemployment and Capital Equipment Accumulation in East Germany.

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Abstract

This paper uses a skill-neutral stochastic dynamic general equilibrium framework to investigate the causes of the unemployment gap observed between east and west Germany in the 1990's. By modifying a traditional matching model of unemployment to include a delay in the investment in capital equipment, we are able to identify and assess the relative importance of factors explaining the portion of the unemployment gap due to deficiencies in business skills and inferior infrastructure as identified by Burda and Hunt (2001). This set-up proposes a propagation mechanism that slows the adjustment in employment following a mismatch shock and/or a technology shock, and consequently provides a rationale for the observed persistent unemployment in Germany.

JEL CLASSIFICATION: E24, J64

1 Introduction

In the last two decades the sharp divergence between US and European unemployment rates has led to what has been termed the "European unemployment puzzle." That is to say, after decades of moving roughly in tandem, since about 1983 Europe has experienced persistent high unemployment while US rates have returned to the

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lows of the 1960s.[1] In Germany alone the number of jobless has recently risen to nearly 4 million, with unemployment in the former East almost double that of the West, inciting both policy makers and academics alike to question why. As such, the underlying reasons and explanations for this divergence of unemployment behavior has become a topic of debate and an important area for research on unemployment behavior. [2] [3] This paper contributes to the literature by developing a stochastic Non-Walrasian mismatch model to investigate the importance of a investment delays in capital equipment in order to explain one potential source of the German unemployment problem.

Stochastic general equilibrium mismatch models have been proposed and investigated for the U.S. (Merz (1995) and Andolfatto (1996)), for Canada (Hornstein and Yuan (1998)), for France (Ibrouk, Maillard, Perelman and Sneessens (2001)), for Spain (Fonseca and Muñoz (1999)), for France and Spain (Sneessens, Fonseca and Maillard (1998)) and, to explain the difference in unemployment rates between Europe and the U.S. (Den Haan, Haefke and Ramey (2001)). In the1980s in Europe, since more than half of the unemployed workers were classified as long-term unemployed,[4] Romer (1996, p. 480) concluded that it seems unlikely that search and matching propagation mechanism could be the source of most of this unemployment. However, Shimer (2002) argues that standard search and matching models are relatively successful in explaining most U.S. labor market stylized facts.[5]

Mismatch models by their nature study internally consistent environments wherein frictions arising from the exchange process are explicitly outlined. Whenever included in the mismatch models, business cycle amplify the effects of shocks on employment.

Matching functions provide a description of these frictions with a minimum added complexity. These models investigate the workings of the exchange process in more detail. Matching models - first applied to the labor market by Shapley and Shubik (1972) - emphasizes that trade in the labor market is costly and uncoordinated due to heterogeneities, frictions and informational asymmetries. Idiosyncratic and aggregate shocks to the productivity of employment matches create an incentive for job destruction and creation. The reallocation of employment across matches is captured by a matching function[6], that is stochastic, and costly in terms of time and resources to the individual. There is a vast literature on matching models, e.g., see the prototype model by Mortensen and Pissarides (1994), Burda (1994), Shi and Wen (1997), Wright (1999).

Studies including the German council of economic experts, SVR, (1994, p. 254), Jackman, Layard and Savouri (1991, p. 71), and Entorf, Franz, König and Smolny (1990) have reported total unemployment estimates of mismatch unemployment in Germany between 20% and 45%. At the lower bound, these estimates translate to 800,000 unemployed individuals. However due to labor market turnover and geographic immobility, one is inclined to suspect that the mismatch in the labor market has increased in importance in recent years.

In Germany, the Bundesanhalt fuer Arbeit or Federal Employment Service (FES) funds temporary employment for individuals who are difficult to place in the employment system. The FES sponsors only forms of work that are socially useful and which without job creation schemes would not be done. The schemes are administered by local authorities and charity organizations. Owing to the size of the long-term unemployed and to the economic restructuring of east Germany, the number of people employed under such schemes reached 35,000 in 1991. These job-creation companies are an important part of the eastern Germany job creation process. We view these job-creation agencies as an implemented solution to alleviate the mismatch in the labor market.

There are potentially important policy implications of this search model. If the results of our analysis indicate that a higher percentage of current east German unemployment is due to a mismatch problem, then policy efforts to reduce unemployment may need to focus on issues relating to improving the matching process and, within the context of this model, the timing of investment in capital equipment. Improvements in the matching process could include a critical examination of the impacts of allowing privatization of some portion of the matching process, currently the exclusive domain of the Bundesanstalt fuer Arbeit. In addition this model provides a formal framework to address and account for the wide disparity in unemployment between former east and west Germany as documented by Burda and Funke (1985) and others.[7]

2 The Model

In our model there exists a continuum of identical individuals of total measure one. Each individual can be employed or unemployed. It is assumed that only the unemployed workers search for a job. Following Langot (1995) and Fonseca and Muñoz (1999) we describe the labor market where trade is costly and uncoordinated. In each period, vacant jobs and unemployed workers are matched. Unemployment persists even in equilibrium because some of the existing jobs break up during the matching process. The separation could for example be due to firm specific shocks, e.g., changes in technology and/or a stochastic component to the matching function to represent the random nature of business skills.

The allocation of resource is governed by a search process that is described by a matching function[8] M_t.

$$M_t \equiv R_t \; h(V_t, U_t) = R_t V_t^{\gamma} {U_t}^{1-\gamma} \tag{1}$$

γ represents the elasticity of hirings with respect to vacancies. U_t denotes the number of job applicants and the size of the population is normalized to one. V_t is the number of job vacancies. We assume that the function $h(.,.)$ exists and is well-behaved. $h_v > 0$, $h_U > 0$, $h(.,.)$ is concave and homogeneous of degree 1. Also, the function satisfies[9] $h(0, U) = h(V, 0) = 0$. See Petrongolo and Pissarides (2001) for an extensive review of the matching function[10] literature. The assumption of constant returns to scale is consistent[11] with the empirical findings of Blanchard and Diamond (1989) for the US and Pissarides (2000) for the UK. Regarding Germany, Burda and Wyplosz (1994) report evidence of a log-linear specification for the matching function; and the statistical hypothesis of CRS[12] is supported by the findings of (Petrongolo and Pissarides 2001, Table 1, p. 398).

The shock R_t refers to a mismatch shock as proposed by Layard, Nickell and Jackman (1991). A positive (negative) shock to R_t increases (reduces) the rate of job finding and consequently shifts the Beveridge curve inward (outward). It follows a stochastic stationary process,

$$\log(R_{t+1}) = \rho_R \log(R_t) + (1-\rho_R)\log(R) + \epsilon_{R,t} \quad (2)$$

$$\epsilon_{R,t} \backsim N(0, \sigma_R) \quad (3)$$

where $\log(R)$ is the unconditional mean of the process and $|\rho_R| < 1$. The shifts to the matching function are due to technological advances[13] in matching. This process is important because, as Petrongolo and Pissarides (2001, p. 399) note "Although changes of this type [technological advances] have been observed recently in most industrial countries (see OECD 1994, and OECD chap 6; 1999) and they have influenced the matching process to the extent that the OECD recommends them to its members as the most cost-effective 'active' labor market policies, they have attracted little formal theoretical or empirical work."

Employment - for firm j and worker i - evolves according to

$$N_{j,t+1} = (1-s)\ N_t + q(\theta_t, R_t)\ V_{j,t} \quad (4)$$

$$N_{i,t+1} = (1-s)\ N_t + p(\theta_t, R_t)\ (1-N_t) \quad (5)$$

where $p(\theta_t, R_t)$ denotes the aggregate transition rate to employment and $q(\theta_t, R_t) \equiv M_t/V_t = R_t h(1, \theta^{-1})$ refers to the rate at which job vacancies are filled. $\theta_t \equiv V_t/U_t$ denotes the tightness of the labor market. Let $s \in (0,1)$ refers to the exogenous[14] separation rate of employment (i.e., the probability that a worker looses her job). Aggregate employment then evolves according to

$$N_{t+1} = (1-s)\ N_t + M_t \quad (6)$$

Equation (6) suggests that a matching in this period, does not become effective employment until the next period. This formal delay is jointly due to the time-nature of search and the required period to train the employees (see Andolfatto 1996, p. 114). In equilibrium, unemployment persists because at each period, a random number of jobs disappear, resulting in new unemployment.

2.1 The Firm

In the model, trade and production are separate activities and the firm can have both filled and unfilled jobs. Only vacant jobs are available for trade. Similarly, only unemployed workers search for a job, i.e., and there is no on-the-job search. The representative firm is a large establishment where the production process requires many workers and the hiring process many job vacancies. Each firm j has access to a constant returns to scale production function and produces a homogeneous good.

$$Y_{j,t} = A_t F(K_{j,t}, N_{j,t} l_t) = A_t K_{j,t}^{\alpha} N_{j,t}^{1-\alpha} \tag{7}$$

where A_t denotes the technology level and l_t refers to the effort level used by firm j to produce its output. A_t is a common to all firms, it follows a stochastic stationary process:

$$\log(A_{t+1}) = \rho_a \log(A_t) + (1-\rho_a)\log(A) + \epsilon_{A,t} \tag{8}$$

$$\epsilon_{A,t} \backsim N(0, \sigma_A) \tag{9}$$

where $\log(A)$ is the unconditional mean of the process and $|\rho_a| < 1$. Firms accumulate capital according to

$$K_{j,t+1} = (1-\delta)K_{j,t} + I_{j,t}^{\psi} I_{j,t-1}^{1-\psi} \tag{10}$$

where δ is the depreciation rate and $0 < \psi < 1$. An investment project initiated at period $t-1$, requires a similar investment in period t to become productive. That is, both I_t and I_{t-1} must increase by one unit (each) to increase $K_{j,t+1}$ by one unit. Installing new units of capital requires effort for two subsequent periods. Instead of formulating two different capital goods that are non-homogeneous and specific[15], we simplify the delay in the investment process by equation (10). The idea is to capture investment in structures and equipment, both of which must coexist in adjacent periods. In other words, an investment project becomes operative only if it is followed by a similar investment in the next period. This captures the crucial point that investment in structures is wasted, if it is not followed by a similar investment in equipments. That is, both investment in structures and equipment are required to increase K_{t+1} by one unit.

This specific formulation of equation (10) captures what Burda and Hunt (2001) describe as the known key development bottleneck in eastern Germany - the lack of investment in capital equipment. For example, between 1991 and 1998, they report figures on cumulative investment in the former East in equipment of 503.6 billion DM compared to the 1094.4 billion DM in structures, whereas comparative figures for the Western states averaged 2071.5 and 2766.5 billion DM investment for *equipment* and *structures*, respectively.

The key innovation in equation (10) then is the parameter ψ. Whenever $\psi = 1$, then equation (10) reduces to the standard RBC time-to-build transition equation. This parameter refers to the share of investment in equipment capital done in period t. In the calibration exercise, we will assume different values for ψ to assess the sensitivity of the results with respect to this parameter. The profit flow of firm j at time t is given by,

$$\Pi_{j,t} = A_t F(K_{j,t}, N_{j,t}) - w_t N_{j,t} - I_{j,t} - \omega V_{j,t} \tag{11}$$

where ω is the cost to post a vacant position. The firm maximizes its discounted flow of profits

$$\max E_0 \left[\sum_{t=0}^{\infty} \rho_t \Pi_{j,t} \right] \equiv \max \sum_{t=0}^{\infty} \int_z \frac{\rho(z_t)}{\rho(z_0)} \Pi_{j,t}(z_t) dz \tag{12}$$

where $\rho_t = \rho(z_t)$ and $\rho(z_0)$ is normalized to one. ρ_t is the pricing kernel[16] (stochastic discount) for the profit flow. $z_t = \{A_t, R_t\}$. The maximization function is subject to two constraints:

$$K_{j,t+1} = (1-\delta) K_{j,t} + I_{j,t}^{1-\psi} I_{j,t-1}^{\psi} \tag{13}$$

$$N_{j,t+1} = (1-s)\ N_{j,t} + q(\theta_t, R_t)\ V_{j,t} \tag{14}$$

The Bellman equation solved by firm j is

$$v_{j,t}(K_{j,t}, N_{j,t}, I_{j,t-1}; z_t) = \max_{\{I_{j,t}, V_{j,t}\}} \left\{ \Pi_{j,t} + E_t \left[\frac{\rho_{t+1}}{\rho_t} v_{j,t+1}(K_{j,t+1}, N_{j,t+1}, I_{j,t}; z_{t+1}) \right] \right\} \tag{15}$$

$$\text{s.t. } K_{j,t+1} = (1-\delta) K_{j,t} + I_{j,t}^{\psi} I_{j,t-1}^{1-\psi} \tag{16}$$

$$N_{j,t+1} = (1-s)\ N_t + q(\theta_t, R_t)\ V_{j,t} \tag{17}$$

The first order conditions:

$$V_{j,t} \quad : \quad -\omega + \Lambda_t^N q(\theta_t, R_t) = 0 \tag{18}$$

$$I_{j,t} \quad : \quad E_t\left[\Lambda_{t+1}^K (1-\psi) I_{j,t+1}^{\psi} I_{j,t}^{-\psi}\right] + \Lambda_t^K \psi I_{j,t}^{\psi-1} I_{j,t-1}^{1-\psi} = 1 \tag{19}$$

$$K_{j,t} \quad : \quad \upsilon_{j,t}^K = \alpha \frac{Y_t}{K_t} + (1-\delta)\Lambda_t^K \tag{20}$$

$$K_{j,t+1} \quad : \quad \int_z \frac{\rho(z_t)}{\rho(z_0)} \upsilon_{j,t+1}^K dz = \Lambda_t^K \tag{21}$$

$$N_t \quad : \quad \upsilon_{j,t}^N = (1-\alpha)\frac{Y_t}{N_t} - w_t + (1-s)\Lambda_t^N \tag{22}$$

$$N_{t+1} \quad : \quad \int_z \frac{\rho(z_t)}{\rho(z_0)} \upsilon_{j,t+1}^N dz = \Lambda_t^N \tag{23}$$

The above system implies the following intertemporal conditions,

$$E_t\left[\Lambda_{t+1}^K (1-\psi) I_{j,t+1}^{\psi} I_{j,t}^{-\psi}\right] + \Lambda_t^K \psi I_{j,t}^{\psi-1} I_{j,t-1}^{1-\psi} = 1 \tag{24}$$

$$\int_z \frac{\rho(z_t)}{\rho(z_0)} \left(\alpha \frac{Y_{t+1}}{K_{t+1}} + (1-\delta)\Lambda_{t+1}^K\right) dz = \Lambda_t^K \tag{25}$$

$$\int_z \frac{\rho(z_t)}{\rho(z_0)} \left((1-\alpha)\frac{Y_{t+1}}{N_{t+1}} - w_{t+1} + (1-s)\frac{\omega}{q(\theta_{t+1}, R_{t+1})}\right) dz = \frac{\omega}{q(\theta_t, R_t)} \tag{26}$$

Note that if $\psi = 1$, then equation (24) reduces to $\Lambda_t^K = 1$, and equation (25) reduces to the standard market clearing condition relating the interest rate to the marginal product of capital and the depreciation rate.

2.2 The household

Depending on the state of employment ($n \equiv$ *employed*, and $u \equiv$ *unemployed*), the CES momentary utility function is

$$U(C_{i,t}^a) = \begin{cases} U^n(C_{i,t}^n - \Gamma^n) = \frac{1}{1-\sigma}\left(C_{i,t}^n - \Gamma^n\right)^{1-\sigma} & \text{if } a = n \\ U^u(C_{i,t}^u - \Gamma^u) = \frac{1}{1-\sigma}\left(C_{i,t}^u - \Gamma^u\right)^{1-\sigma} & \text{if } a = u \end{cases} \tag{27}$$

where $C^a_{i,t}$ denotes consumption contingent on the status of the worker in the labor market $a = n$ employed or $a = u$ unemployed. Regardless of skills, separation is exogenous. In terms of consumption units, Γ measures the disutility from working (Γ^n) and from being unemployed (Γ^u). Each agent maximizes the discounted sum of her expected momentary utility.

$$\max_{\left\{C^a_{i,t}, S_{i,t}, B^a_{i,t}\right\}_{a=n,u}} E_0 \left(\sum_{t=0}^{\infty} \beta^t \left[p_{t-1} U^n (C^n_{i,t} - \Gamma^n) + (1 - p_{t-1}) U^u (C^u_{i,t} - \Gamma^u) \right] \right) \tag{28}$$

Given the stochastic nature of the endowment stream, we allow for full-unemployment insurance to exist.[17] The agent uses savings to insure herself against income fluctuations.

$$C^n_{i,t} + \tau_t S_{i,t} + \int_Z \frac{\rho(z_{t+1})}{\rho(z_t)} B^n_{i,t+1}(z_{t+1}) f(z_{t+1}|z_t) dz_{t+1} \leq w_t l_t + d_{i,t} + B^n_{i,t} \tag{29}$$

$$C^u_{i,t} + \tau_t S_{i,t} + \int_Z \frac{\rho(z_{t+1})}{\rho(z_t)} B^u_{i,t+1}(z_{t+1}) f(z_{t+1}|z_t) dz_{t+1} \leq S_{i,t} + d_{i,t} + B^u_{i,t} \tag{30}$$

$$(1 - s) N_t + p_t (1 - N_t) = N_{t+1} \tag{31}$$

where $S_{i,t}$ is the insurance claim (unemployment compensation) and its price is τ_t. $B_{i,t}$ refers to the accumulated asset in terms of the physical consumption good. $d_{i,t}$ denotes the dividend payment to the household arising from equity ownership in the firm.

For the $\sigma = 1$ specification, the first order conditions:

$$C^n_{i,t} \; : \quad (C^n_{i,t} - \Gamma^n)^{-1} = \Lambda^n_{i,t} \tag{32}$$

$$C^u_{i,t} \; : \quad (C^u_{i,t} - \Gamma^u)^{-1} = \Lambda^u_{i,t} \tag{33}$$

$$S_{i,t} \; : \quad -p_t \Lambda^n_{i,t} \tau_t - (1 - p_t) \Lambda^u_{i,t} (1 - \tau_t) = 0 \tag{34}$$

2.3 The Insurance Company

The insurance company maximizes its profits as,[18]

$$\pi = \tau_t S_t - (1-p)S_t \tag{35}$$

The solution to the above problem is $\tau_t = 1 - p_t$. Substituting this result into equation (34), yields

$$\Lambda_{i,t}^n = \Lambda_{i,t}^u = \Lambda_{i,t} \tag{36}$$

$$C_{i,t}^n - \Gamma^n = C_{i,t}^u - \Gamma^u \qquad (\forall i) \tag{37}$$

Substituting into the consumer constraints and solving equations (29) and (30), yields the full insurance equilibrium condition for the household,

$$S_{i,t} = w_t l_t - \Gamma^u + \Gamma^n \tag{38}$$

Note that this equilibrium is sub-optimal since the labor market is not clearing. Given their small size and inability to influence the market, both the firm and the household take the wage rate as given in their optimization function, respectively. However, in this framework of bilateral monopoly, the wage rate, as well as the search effort, are determined within a bargaining framework.

2.4 Wage Determination

Once a match is formed, both the worker and the firm have monopoly powers. Keeping a match generates a gain relative to the alternative of no match for both agents. In the [alternative] latter case, the worker remains unemployed and the firm keeps the job vacant. Given the monopoly power, any wage level that gives each agent a non-negative match surplus is consistent. Therefore, to determine the wage level, we assume that the match surplus is divided using Nash bargaining,

$$\max_{w_{i,j,t},l_{i,j,t}} \left(\Omega_{i,t}^{H}\right)^{\lambda} \left(\Omega_{j,t}^{F}\right)^{1-\lambda} \tag{39}$$

where $\Omega_{i,t}^{H}$ refers to the match rent for the worker and $\Omega_{j,t}^{F}$ refers to the match rent for the firm. λ denotes the worker bargaining power and $0 \leq \lambda \leq 1$. The household match rent is given by the net expected actualized sum of the work disutility and the search effort disutility[19]

$$\Omega_{i,t}^{H} = \left[w_{i,j,t} - \Gamma^{n} + \Gamma^{u}\right] + \beta\left(1 - s - p_{t}\right) E_{t}\left[\Omega_{i,t+1}^{H}\right] \tag{40}$$

The firm match rent is given by the marginal real value of employment[20]

$$\Omega_{j,t}^{F} = \frac{\partial \upsilon(.)}{\partial N_{j,t}} = A_{t}\frac{\partial F_{j,t}}{\partial N_{j,t}} - w_{i,j,t} + (1-s)E_{t}\left[\frac{\rho_{t+1}}{\rho_{t}}\Omega_{j,t+1}^{F}\right] \tag{41}$$

The resulting first order condition:

$$\frac{\lambda}{1-\lambda}\Omega_{j,t}^{F} = \Omega_{i,t}^{H} \tag{42}$$

yeilds the sharing rule of the match rent between the firm and the worker. Solving this equation yeilds the wage-setting rule

$$w_{t} = \lambda A_{t}\frac{\partial F}{\partial N_{t}} + (1-\lambda)\left(\Gamma^{n} - \Gamma^{u}\right) \tag{43}$$

Here the wage is a weighted sum of the worker's marginal product and the reservation wage. The equilibrium wage lies between the reservation wage and the marginal product of labor. The worker gets a fraction λ of the match surplus and the firm gets (1- λ) .

2.5 Rational Expectations Equilibrium

The rational expectation equilibrium is characterized by

$$\left(C_{i,t}^{n}-\Gamma^{n}\right)^{-1} = \Lambda_{i,t}^{n} \tag{44}$$

$$\left(C_{i,t}^{u}-\Gamma^{u}\right)^{-1} = \Lambda_{i,t}^{u} \tag{45}$$

$$\lambda(1-\alpha)\frac{Y_t}{N_t}+(1-\lambda)\left(\Gamma^{n}-\Gamma^{u}\right) = w_t \tag{46}$$

$$(1-\delta)K_t+A_tF(K_t,N_t)-\omega V_t-N_tC_t^{n}-(1-N_t)C_t^{u} = K_{t+1} \tag{47}$$

$$(1-s)N_t+R_tV_t^{\gamma}(1-N_t)^{1-\gamma} = N_{t+1} \tag{48}$$

$$E_t\left[\Lambda_{t+1}^{K}(1-\psi)I_{j,t+1}^{\psi}I_{j,t}^{-\psi}\right]+\Lambda_t^{K}\psi I_{j,t}^{\psi-1}I_{j,t-1}^{1-\psi} = 1 \tag{49}$$

$$\int_z\frac{\rho(z_t)}{\rho(z_0)}\left(\alpha\frac{Y_{t+1}}{K_{t+1}}+(1-\delta)\Lambda_{t+1}^{K}\right)dz = \Lambda_t^{K} \tag{50}$$

$$\int_z\frac{\rho(z_t)}{\rho(z_0)}\left((1-\alpha)\frac{Y_{t+1}}{N_{t+1}}-w_{t+1}+(1-s)\frac{\omega}{q_{t+1}}\right)dz = \frac{\omega}{q_t} \tag{51}$$

The last equation describes the evolution of the implicit price of employment. The firm chooses the level of vacancies such that the marginal value of its employment is equal to the cost of vacancy. The set of the above equations define a general equilibrium that can not be solved analytically. We therefore log-linearize the system around the deterministic steady state, impose the Hosios efficiency condition, and proceed to solve the rational expectations linearized dynamic system using brute force as outlined by Uhlig (2001).

3 Calibration and Results

Burda and Hunt (2001, p. 68) report the estimated depreciation rate as $\delta = 9.4\%$. The parameter ψ is calibrated to match the investment in equipment capital relative to structures capital in east Germany (Burda and Hunt (2001, Table 5, p. 13)). For east Germany, we therefore set $\psi = 0.25$ to reflect the share of investment in equipment. For west Germany, ψ is set to 0.45. A sensitivity analysis is performed over the grid $\psi \in \{0.25, 0.45\}$. The share of capital is set to $\alpha = 0.35$. Burda and Wyplosz (1994) estimated a Cobb-Douglas matching function and reported that the elasticity of hiring relative to vacancies is $\gamma = 0.25$. Note that for France, Langot (1995) set this parameter to 0.58 and for Spain, Fonseca and Muñoz (1999) calibrate it to 0.15 based on the estimation results reported in Castillo et al. (1998). We impose the Hosios (1990) efficiency[21] condition $\lambda = 1 - \gamma = 0.75$ to reflect the worker bargaining power. Given the relatively high worker bargaining power and the strong union membership in Germany, we set the separation rate to 0.08. The degree of labor market tighness θ is set to 0.10 as in Langot (1995). The Technology (A_t) and Matching (R_t) shocks follow $\rho_A = \rho_R = 0.95$ and $\sigma_A = \sigma_R = 0.01$.

Table 1: Calibration Parameters

β	α	δ	ψ	λ	γ	s	θ	N	ω	Γ^n	Γ^u
0.99	0.35	0.094	0.25	0.75	0.25	0.08	0.10	0.65	0.32	0.95	0.10

The parameters are chosen to ensure that the capital to output steady state value equals 4.58 as reported in Burda and Hunt (2001, p. 69). We solve and simulate the model with sensitivity to the structure following Uhlig (2001, p. 38). The log-linearized system is solved using numerical rational expectations.[22] We simulated 50 (200 observations) time series for each variable and then computed the correlation of each variable with respect to the model generated output, as well as the small sample standard error. Since our focus is not to address the relative merit of each shock with respect to the business cycle variability, we do not separate the results by type of shock. Our focus is on the delay in capital equipment investment and its relative merit in explaining the unemployment gap. Therefore, we present and analyze the volatility and impulse responses results where emphasis is on the intensity in the delay parameter ψ.

Table 2: Standard Deviation Relative to Output

	$\psi = 0.25$	$\psi = 0.30$	$\psi = 0.35$	$\psi = 0.40$	$\psi = 0.45$
Employment	0.36	0.38	0.39	0.40	0.40
	(0.02)	(0.03)	(0.03)	(0.04)	(0.04)
Investment	5.18	4.75	4.50	4.33	4.25
	(0.23)	(0.24)	(0.24)	(0.28)	(0.37)
Vacancy	5.10	5.36	5.48	5.53	5.66
	(0.30)	(0.34)	(0.36)	(0.45)	(0.56)
Wage	0.48	0.47	0.46	0.45	0.44
	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)

All variables are logged and detrended using the Hodrick-Prescott filter.
Numbers in parenthesis are the standard deviation (absolute, not relative to output) of the standard deviation of each variable.

Table 2 results suggest that as the share of investment in capital equipment increases, the volatility of investment decreases and vacancies displays higher volatility. As investment become at par between equipment and structures (moves toward 0.5), then variability in vacancies reflect the effects of both shocks: technology and mismatch, and therefore, it increases.

Figure 1 traces the effects of each shock on labor and vacancies. The technological and matching shocks have opposite effects on the relationship between unemployment and vacancies. An aggregate technology shock causes a movement on the Beveridge curve towards more vacancies and less unemployment. A (positive) matching shock causes the Beveridge curve to shift inward, therefore creating less vacancies and less unemployment. Therefore, the introduction of mismatch shocks lower the simulated correlation between unemployment and vacancies. The model can generate non-Walrasian features of the labor market. Unemployment is involuntary and it does persist for at least 4 years.

In Figure 1, the model suggests that 1.5 percent of the unemployment gap between east and west Germany could be eliminated if east Germany increases its investment in capital equipment to a level comparable to its western counterpart.

4 Conclusions

Previous empirical studies have shown that the mismatch hypothesis - as a stand alone - has had difficulty in accounting for a large fraction of fluctuations in European employment. Using an alternative model which combines a mismatch model with a delay in investment for equipment capital, we show that much of the unemployment gap can be explained in Germany. Conditioned on the model and calibrated parameters, our model suggests that an equiproportionate investment in structures and equipment tend to smooth investment volatility and consequently the business cycle. Results point to 1.5 percent unemployment differential between an economy that invests little in equipment relative to investment in structures. As a policy consequence, results suggest that increasing the pace and intensity of investment in capital equipment in east Germany may reduce overall unemployment by as much as 1.5 percentage points.

Notes

[1]European OECD unemployment exceeds the overall OECD average by two percentage points.

[2]On the demand side, see Blanchard and Summers (1986), Lindbeck and Snower (1988), Bentolila and Bertola (1990) and Malinvaud (1994). On the supply side, see Blanchard and Wolfers (2000) Ljungqvist and Sargent (1996). For institutional explanation, see Den Haan, Haefke and Ramey (2001).

[3]Among many, firing costs were motivated, formulated and investigated (see Bentolila and Bertola (1990) and Prewo and Franke (1998, p. 4)).

[4]The long-term unemployed is a job seeker who spent more than a year without a job. See Bean (1994).

[5]Four out five outlined stylised facts were accounted for using a standard search and matching model.

[6]The matching function is a device that captures the implications of the costly trade without the need to formally address heterogeneity. It summarizes the trading technology between heterogeneous agents without being explicit about it.

[7]Results may also have broader policy implications for organizations such as the European Social Fund (ESF) and the European Foundation for the Improvement of Living and Working Conditions.

[8]This well-behaved matching function has a parallel in the neoclassical assumption of the existence of an aggregate production function.

[9]Note that for large V, the following is true: $\exp\left(-\frac{eU}{V}\right) \simeq \left[1-\frac{1}{V}\right]^{eU}$

[10]Gale and Shapely (1962) showed that *stable* matching always exists whenever the agents preferences are uncomplicated. *Stable* is defined as follows. The matching is said to be *stable* only if it left no pair of agents on opposite sides of the market who were not matched to each other but would prefer to be.

[11]Also, in a growing economy, the assumption of CRS ensures a constant unemployment rate along the balanced-growth path.

[12]With constant returns to scale (CRS), one can think of the matching process as one in which an unemployed draw “balls” (applications) from a box (the stock of vacancies). If each unemployed worker applies to a one randomly selected vacancy and the number of vacancies and unemployed is sufficiently large, the probability of an un-filled vacancy will be $\exp\left(-\frac{U}{V}\right)$. The probability of a vacancy having at least one applicant is $1-\exp\left(-\frac{U}{V}\right)$. At the aggregate, hiring eqauls to $V\left(1-\exp\left(-\frac{U}{V}\right)\right)$, which has a constant return to scale.

[13]Technological advances include reforms such as the computerization of employment offices, job advertising on the internet, an increase in the resources that governments put into subsidized matching.

[14]One could assume that the seperation rate s_t is negatively correlated to the aggregate

technology shock. Formally, $s_t = \overline{s}A_t^{-\phi}$. It could be argued that a technology shock would result in a higher separation rate (i.e., positively correlated) because skills become obsolete. At this point, the model will not exhibit skill-neutrality. Burda and Hunt (2001, p. 64) point out that for Germany, the unskilled labor force hypothesis is an unlikely explanation for the unemployment gap. Therefore, we assume that the seperation rate is exogenous and unrelated to changes in the technological environment.

[15]An alternative formulation could be $K_{j,t+1} = (1-\delta)K_{j,t} + I_{j,t}$ where $K_{j,t} = K_{j,t}^E + K_{j,t}^S$. Note that $K_{j,t}^E \equiv \phi K_{j,t}$ and $K_{j,t}^S \equiv (1-\phi)K_{j,t}$. Here, we would have to specify, how each capital is accumulated and how it enters the production process. The parameter ϕ will have to assume the role of ψ in equation (10). Note also, that Burda and Hunt (2001, p. 68) reported the estimates for the depreciation rates as follows: $\delta_E = 7.5\%$ and $\delta_S = 12.3\%$.

[16]In general, let $Q_j(x^j, x)$ denotes the j-step ahead state contingent price, where x is the state and it follows a continuous Markov process. Then the Lucas asset pricing formula is written as, $Q_j(x^j, x) = \beta^j \frac{u'(x^j)}{u'(x)} f^j(x^j, x)$ where the j-step-ahead transition function obeys $f^j(x^j, x) = \int f(x^j, x^{j-1}) f^{j-1}(x^{j-1}, x) dx^{j-1}$ and $\Pr\{x_{t+j} \leq x^j | x_t = x_t\} = \int_{-\infty}^{x^j} f^j(w, x) dw$

[17]This assumption of the model is consistent with the stylized fact that most workers have unemployment insurance in Germany since it is mandatory for all full time non-self-employed workers.

[18]We note that in the case of Germany, the "insurance company" is effectively the Bundesanstalt fuer Arbeit.

[19]$\Omega_{i,t}^H$ is the difference between $\Theta_{i,t}^n = [w_{i,j,t} - \Gamma^n] + E_t\left[\frac{\rho_{t+1}}{\rho_t}\left\{(1-s)\Theta_{i,t+1}^n + s\Theta_{i,t+1}^n\right\}\right]$ and $\Theta_{i,t}^u = -\Gamma^u + E_t\left[\frac{\rho_{t+1}}{\rho_t}\left\{p(\theta_t, R_t)\Theta_{i,t+1}^n + (1 - p(\theta_t, R_t))\Theta_{i,t+1}^u\right\}\right]$

[20]Note that the firm optimality condition is $E_t\left[\frac{\rho_{t+1}}{\rho_t}\frac{\partial V_{t+1}}{\partial N_{t+1}}\right] = E_t\left[\frac{\rho_{t+1}}{\rho_t}\Omega_{t+1}^F\right] = E_t\left[\beta\frac{\Lambda_{t+1}}{\Lambda_t}\Omega_{t+1}^F\right] = \frac{\omega}{q(\theta_t, X_t)}$ where Λ is the lagrange multiplier associated with the household budget.

[21]Agents take the matching rates as given. However, their actions (together) influence these rates, and hereby creating externalities. These externalities can be negative or positive. For example, when a firm increases the number of vacancies, it increases congestion for other firms' vacancies (negative) and it increases the chance for unemployed workers to find a job (positive). These externalities cancel out when the two sides of the market are rewarded according to their contributions to the match formation, i.e., $\lambda = \frac{U}{h(.,.)}\frac{\partial h(.,.)}{\partial U}$ and $1 - \lambda = \frac{V}{h(.,.)}\frac{\partial h(.,.)}{\partial V}$.

[22]See the Appendix for details.

5 Appendix:

5.1 The Steady State

To compute the steady state for the system, we solve the following using *fsolve.m*,

$$0 = \overline{N} - \frac{1}{s}\overline{q}\overline{V} \tag{52}$$

$$0 = \overline{q} - \overline{RV}^{\gamma-1}(1-\overline{N})^{1-\gamma} \tag{53}$$

$$0 = \overline{Y} - \overline{AK}^{\alpha}\overline{N}^{1-\alpha} \tag{54}$$

$$0 = \overline{K} - \frac{1}{\delta}\overline{I} \tag{55}$$

$$0 = \alpha\frac{\overline{Y}}{\overline{K}} + 1 - \delta - \frac{1}{\beta} \tag{56}$$

$$0 = (1-\alpha)\frac{\overline{Y}}{\overline{N}} - \overline{W} + (1-s)\frac{\omega}{\overline{q}} - \frac{\omega}{\beta\overline{q}} \tag{57}$$

$$0 = \overline{C}^{n} - \overline{C}^{u} - \Gamma^{n} + \Gamma^{u} \tag{58}$$

$$0 = \overline{W} - \lambda(1-\alpha)\frac{\overline{Y}}{\overline{N}} + (1-\lambda)(\Gamma^{n} - \Gamma^{u}) \tag{59}$$

$$0 = \overline{Y} - \omega\overline{V} - \overline{NC}^{n} - (1-\overline{N})\overline{C}^{u} - \delta\overline{K} \tag{60}$$

5.2 The log-linearized System

The log-linearized system is,

$$\overline{C}^n + \overline{C}^n c_t^n - \overline{C}^u - \overline{C}^u c_t^u = -\Gamma^u + \Gamma^n \tag{61}$$

$$\begin{bmatrix} \left((1-\alpha)\lambda\frac{\overline{Y}}{\overline{N}}\right)(1+y_t-n_t) \\ +(1-\lambda)(\Gamma^n-\Gamma^u) \end{bmatrix} = \overline{W} + \overline{W}w_t \tag{62}$$

$$\begin{bmatrix} (1-\delta)\left[\overline{K}+\overline{K}k_t\right] + \left(\overline{Y}+\overline{Y}y_t\right) \\ -(\omega\overline{V}+\omega\overline{V}v_t) \\ -(\overline{NC}^n + \overline{NC}^n n_t + \overline{NC}^n c_t^n)- \\ (\overline{C}+\overline{C}c_t^u) \\ +(\overline{NC}^u + \overline{NC}^u n_t + \overline{NC}^u c_t^u) \end{bmatrix} = \overline{K} + \overline{K}k_{t+1} \tag{63}$$

$$\overline{AK}^{\alpha}\overline{N}^{1-\alpha}(1+a_t+\alpha k_t+(1-\alpha)n_t) = \overline{Y}+\overline{Y}y_t \tag{64}$$

$$\begin{bmatrix} (1-s)(\overline{N}+\overline{N}n_t)+ \\ \left[\overline{RV}^{\gamma}(1-\overline{N})^{1-\gamma}\right](1+r_t+\gamma v_t+(1-\gamma)(1-n_t)) \end{bmatrix} = \overline{N}+\overline{N}n_{t+1} \tag{65}$$

$$(1-\delta)(\overline{K}+\overline{K}k_t) + \overline{I}_t^{\psi}\overline{I}_{t-1}^{1-\psi}(1+\psi i_t+(1-\psi)i_{t-1}) = \overline{K}+\overline{K}k_{t+1} \tag{66}$$

$$E_t\begin{bmatrix} (1-\psi)\overline{\Lambda}_{t+1}^{K}\overline{I}_{t+1}^{\psi}\overline{I}_t^{-\psi}(1+\lambda_{t+1}^k+\psi i_{t+1}-\psi i_t)... \\ +\overline{\Lambda}_t^{K}\overline{I}_t^{\psi-1}\overline{I}_{t-1}^{1-\psi}\psi \\ (1+\lambda_t^k+(\psi-1)i_t+(1-\psi)i_{t-1}) \end{bmatrix} = 1 \tag{67}$$

$$E_t\beta\begin{bmatrix} \alpha\frac{\overline{Y}}{\overline{K}}(y_{t+1}-k_{t+1})+ \\ (1-\delta)\left(\overline{\Lambda}_{t+1}^{K}+\overline{\Lambda}_{t+1}^{K}\lambda_{t+1}^k\right) \end{bmatrix} = \overline{\Lambda}_t^{K}+\overline{\Lambda}_t^{K}\lambda_t^k \tag{68}$$

$$E_t\beta\begin{bmatrix} \left((1-\alpha)\frac{\overline{Y}}{\overline{N}}\right)(y_{t+1}-n_{t+1}) \\ -\left(\overline{W}+\overline{W}w_{t+1}\right) \\ +(1-s)\omega\overline{R}^{-1}\overline{V}^{1-\gamma}(1-\overline{N})^{\gamma-1} \\ (1-r_{t+1}+(1-\gamma)v_{t+1}+(\gamma-1)n_{t+1}) \end{bmatrix} = \begin{bmatrix} \omega\overline{R}^{-1}\overline{V}^{1-\gamma}(1-\overline{N})^{\gamma-1} \\ \begin{pmatrix} 1-r_t \\ +(1-\gamma)v_t \\ +(\gamma-1)n_t \end{pmatrix} \end{bmatrix} \tag{69}$$

5.3 Rational Expectations

Write the log-linearized system as,

$$0 = Ax_t + Bx_{t-1} + Cy_t + Dz_t \tag{70}$$

$$0 = E_t\left[Fx_{t+1} + Gx_t + Hx_{t-1} + Jy_{t+1} + Ky_t + Lz_{t+1} + Mz_t\right] \tag{71}$$

$$z_{t+1} = Nz_t + \epsilon_{t+1} \qquad E_t\left[\epsilon_{t+1}\right] = 0 \tag{72}$$

where x_t denotes the state vector, y_t refers to the jump variables and z_t refers to the exogenous ones. It is assumed that N has only stable eigenvalues. Using Theorem

3.2 in Uhlig (2001, p. 38), we solve for the recursive equilibrium law of motion

$$x_t = Px_{t-1} + Qz_t \tag{73}$$
$$y_t = Rx_{t-1} + Sz_t \tag{74}$$

To compute the P, Q, R and S matrices, we solve,

$$0 = C^0AP + C^0B \tag{75}$$
$$0 = (F - JC^+A)P^2 - (JC^+B - G + KC^+A)P - KC^+B + H \tag{76}$$
$$R = -C^+(AP + B) \tag{77}$$
$$V = \begin{bmatrix} I_k \otimes A & I_k \otimes C \\ N' \otimes F + I_k \otimes (FP + JR + G) & N' \otimes J + I_k \otimes K \end{bmatrix} \tag{78}$$
$$V \begin{bmatrix} vec(Q) \\ vec(S) \end{bmatrix} = - \begin{bmatrix} vec(D) \\ vec(LN + M) \end{bmatrix} \tag{79}$$

given that all eigenvalues of P are less than unity in absolute value. We choose the root(s) manually. C^+ denotes the pseudo-inverse of C. $C^+ = (C'C)^{-1}C'$. $C^0 \equiv (null(C'))'$. The C^0 is found by singular value decomposition of C'. Note that $C^0C = 0$.

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6 Figure:

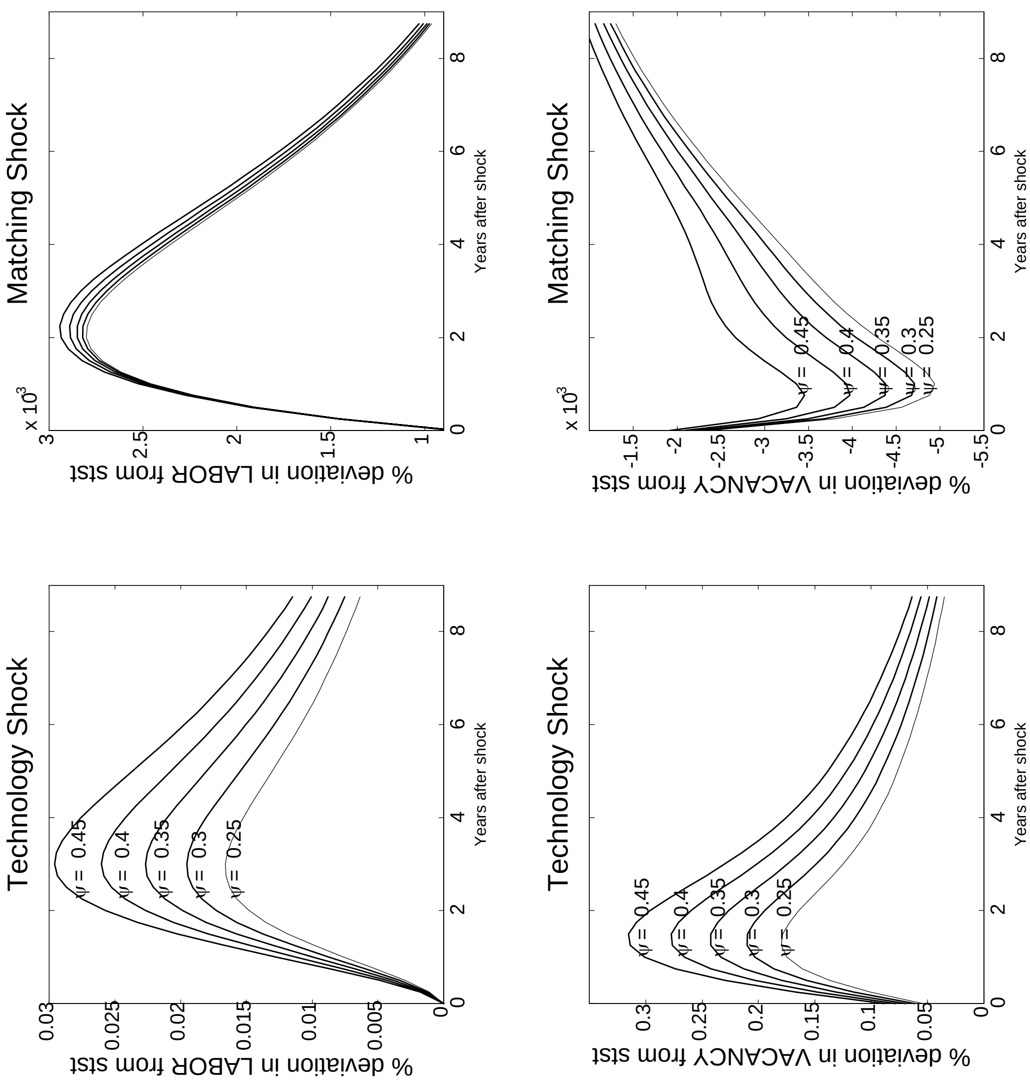

Figure 1: Impulse Responses and the Beveridge Curve