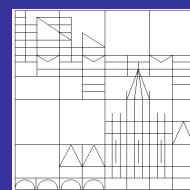




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# Temporary Layoffs with Incomplete Worker Attachment in Search Equilibrium

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## Abstract

This paper revisits the no-attachment assumption in job search models with random productivity fluctuations and Nash-bargaining. Both workers and firms value the option to remain in attachment: firms profit from a reduced hiring cost, while workers gain from a higher reservation wage when bargaining with a new employer. Ex-post differentiation of workers into attached and unattached unemployed produces endogenous binary wage dispersion. The decentralized equilibrium with a Hosios value of the bargaining power is no longer constrained efficient: when changing attachment workers impose a negative externality on their former employer originating from a loss of the recall option. This inefficiency tends to produce excessive job creation. The paper also investigates returns to job mobility in Germany and shows that being recalled to the previous employer as opposed to the new job is associated with about 8% lower probability of wage improvement.

**JEL classification:** J23, J31, J63, M51

**Keywords:**

Search equilibrium, temporary layoff, constrained efficiency, wage dispersion

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# 1 Introduction

The process of job destruction is well understood and incorporated into the models of job search. The seminal work in this field is accomplished by Mortensen and Pissarides (1994) with the following studies by Pissarides (2000), Bontemps, Robin and Van den Berg (2000) and Postel-Vinay and Robin (2002a). The general framework for the analysis of job destruction builds up on the mechanism of permanent, independent and idiosyncratic productivity shocks inducing agents to separate. As a result of the negative productivity shock jobs are destroyed while workers are unemployed and search for a new employment. Nevertheless the common assumption of permanent separations and memoryless behavior of workers and firms contradicts the existing empirical literature. Mavromaras and Rudolph (1998) show that 26.5% of the individuals finding employment in Germany are recalled to their former employers (table 1).

Study	Results	Sample (spells)	Country
K. Mavromaras, H. Rudolph (1998)	Recalls: 26.5%	N=22601 (L)	Germany 1980-1990
G. Fischer, K. Pichelmann (1991)	Recalls: 32.4% AU: 22.2%	N=2499 (T)	Austria 1985
A. Alba-Ramirez, J. Arranz, F. Munoz-Bullon (2007)	Recalls: 35.7%	N=23035 (L)	Spain 1999-2002
P. Jensen, M. Svarer (2003)	Recalls: 50% AU: 20%	N=35000 (T)	Denmark 1981-1990
F. Jansson (2002)	Recalls: 40-47% AU: 10%	N=3668 (T)	Sweden 1995-1996
K. Roed, M. Nordberg (2003)	Recalls: 32.2% AU: 13.3%	N=815373 (T)	Norway 1989-1998

AU – attached unemployment; L – layoff unemployment; T – total unemployment;

Table 1: Summary of empirical research on temporary layoffs (Europe)

Similar frequencies of recalls are registered in Austria and Spain being respectively 32.4% and 35.7%. Even higher recall ratios are estimated in Scandinavian countries ranging from 32.2% in Norway to about 50% in Denmark. In addition, empirical relevance of temporary layoffs is supported by the fractions of attached unemployed (expecting a recall) in the pool of unemployed workers. These ratios range from ap-

proximately 10% in Sweden to 22.2% in Austria. Temporary layoffs are also a widespread phenomenon in the U.S. According to the data of the U.S. Bureau of Labor Statistics for the period 2000-2007, approximately 1 million of registered unemployed in the U.S. expect to be recalled to their former employers<sup>1</sup>. This corresponds to the ratios of 13.6% of total unemployment and 26.4% of layoff unemployment in the U.S.

Following the empirical evidence this study considers the problem of temporary layoffs in a model of job search. The starting point of this paper is to introduce temporary productivity shocks and worker-firm attachment into the search and matching framework of Mortensen and Pissarides (1994), where search is random and undirected and wages are set via the Nash bargaining. Bargaining as a wage determination mechanism is supported on the empirical level, e.g. using the data from Princeton Data Improvement Initiative for the year 2008 Hall and Krüger (2008) find that about a third of all workers in the sample bargained with their current employers rather than treated their job offer as take-it-or-leave-it. Further, this study considers wage contracts with limited commitment and allows for wage renegotiations if either of the participation constraints is binding.

Conditionally on productivity shocks being sufficiently severe for the threat of lay-off to be credible there are two different equilibria. The first equilibrium obtains at low variation in productivity, the layoff threat is then eliminated by wage renegotiation implying a wage reduction after the first production spell. The second equilibrium with temporary layoffs obtains at high productivity variation and is in the focus of the present study. First of all, search costs incurred by firms as well as a temporary nature of productivity fluctuations mutually motivate the worker-firm attachment upon a separation. Nevertheless, worker's attachment is incomplete, since workers search for new job alternatives during the low productivity spells. Both workers and firms gain from their attachment. Firms obtain a valuable option to recall the worker, while workers gain from an additional possibility to be recalled. There is also a second gain for the workers: attached unemployed have a higher reservation wage than the unattached, which means they can bargain a higher wage when contacted by a new employer. The ex-post differentiation of reservation wages among attached and unattached unemployed produces a binary wage distribution in the equilibrium. The model can thus contribute to the debate on endogenous wage dispersion following the seminal study

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<sup>1</sup>Individuals on a temporary layoff are defined as those "who have been given a date to return to work or who expect to return within 6 months", U.S. Bureau of Labor Statistics, Handbook of Methods, Chapter 1, available at [www.bls.gov/opub/hom](http://www.bls.gov/opub/hom)

by Burdett and Mortensen (1998).

Furthermore, this study confirms theoretical predictions of the model using the data from the German Social-Economic Panel for the years 2003-2007. The probit regression model shows that workers recalled to their previous employer face approximately 8% lower probability of wage improvement compared to those finding a job with a new employer. This means that the worker-firm attachment and recalls have significant predictive power for wage changes and therefore provide an additional explanation of wage heterogeneity in Germany. Other significant explanatory variables include age of the individual, the reason for separation as well as comparison of job characteristics. This study shows that voluntary separations are associated with 6.5% higher probability of wage improvement upon a job change, at the same time the probability is 8.2% lower in the case of involuntary separation. Moreover, additional benefits, better promotion possibilities and improved job security are positively associated with wage gains.

Finally, this study considers welfare properties of an economy with search frictions and temporary layoffs. I find that the decentralized equilibrium with temporary layoffs is constrained inefficient even if search externalities are internalized. Hosios (1990) shows that search externalities are an inherent feature of models with stochastic matching and wage bargaining, since matching takes place before the bargaining, so that wages do not perform any allocative or signaling function. This study shows that mutual attachment of workers and firms upon a negative productivity shock introduces a new source of the equilibrium inefficiency. The novel attachment externality results from the fact that workers on a temporary layoff accepting new jobs do not internalize the losses imposed on their previous employer. The previous firm is losing an option to recall the former employee, which is immediately translated into a value loss, since hiring is costly and time-consuming in the model.

To separate search and attachment externalities I set the bargaining power parameter equal to the elasticity of the matching function. According to Hosios (1990) this condition guarantees that search externalities are internalized. Then the decentralized equilibrium with temporary layoffs is characterized by excessive job creation. Profits of firms hiring workers from attached unemployment are inefficiently high, so that too many jobs are created in the equilibrium. This paper also shows, that efficiency of the decentralized equilibrium may be restored by imposing an income tax on attached

unemployment starting job with a new employer. The present value of tax payments from a match should then be equal to the value loss of the previous employer of the worker.

The plan of the paper is as follows. Section 2 contains an overview of the literature while section 3 explains notation and the general economic environment of the model. Section 4 presents a model with temporary layoffs and section 5 explains the model with wage renegotiation. Section 6 contains welfare analysis of the decentralized equilibrium with temporary layoffs while section 7 contains an empirical test of model predictions using data from the German labour market. Section 8 concludes.

## **2 Overview of the related literature**

There are a number of features relating this study to the existing literature. Originally the theory of temporary layoffs has been developed in the implicit contract framework represented by the studies of Baily (1977), Feldstein (1976, 1978) and Burdett and Wright (1989). Feldstein (1976) considers the option of firms to reduce employment versus the option to reduce working hours in response to random demand fluctuations. Workers are assumed to be permanently attached to the firm and receive unemployment benefits if not employed. Unemployment benefits are financed by a tax on firms that is related to the previous benefits collected by the firm's employees (imperfect experience rating). Feldstein (1976) shows that imperfect experience rating magnifies the effect on employment of changes in demand and increases the change in employment relative to the change in average hours. Burdett and Wright (1989) allow firms to choose both the number of workers under the contract (firm size) and the number of workers producing output in a given period of time, so the model is characterized by attached and unattached unemployment, this properties however are achieved at the expense of assuming indivisible labour supply. Given this properties Burdett and Wright (1989) show that the major result of Feldstein (1976) is reversed, so that an increase in experience rating increases unemployment under reasonable conditions.

One-sided labour demand analysis of the implicit contract literature is extended to consider the labour supply side of the market in the literature of job search. This is represented by the studies of Burdett and Mortensen (1980), Pissarides (1982) and Mortensen (1990). Burdett and Mortensen (1980) is the first study to synthesize the search and the implicit contract approaches. This study considers a labour market with

an exogenous wage offer distribution where each job is additionally characterized by a particular layoff probability. Moreover Burdett and Mortensen (1980) allow workers to search on a temporary layoff, however search is costly implying a positive reservation wage for attached workers. Burdett and Mortensen (1980) characterize a retention equilibrium where expected wage obtained by the worker is sufficiently high to prevent the search in attachment. This is different from the current study where workers search on a temporary layoff and change the attachment as soon as a new wage offer is obtained. This property is achieved by the use of Nash bargaining in wage setting, leaving positive rent to the worker.

Pissarides (1982) considers search behavior of workers in attached unemployment facing an exogenous wage offer distribution. The new feature of the model is that recall probability is endogenous and is optimally chosen by firms. Pissarides (1982) shows that workers search for an alternative job only if the probability of recall falls below a critical level, and that firms may recall workers before the recovery of demand, depending on the costs of laying off and hiring. Another study considering the problem of temporary layoffs in a partial equilibrium framework is Mortensen (1990), who considers a situation where workers search and receive wage offers both when employed and unemployed and the worker's productivity on any specific job is subject to continual stochastic disturbance over time. This setup provides explanations for job to job transitions of workers as well as the phenomena of temporary layoffs and recalls. The focus of Mortensen (1990) is on the effect of unemployment benefits on worker's optimal search behavior, in particular he shows that both the incidence and duration of unemployment increase with the UI benefit ratio but the effect on the incidence of attached unemployment is larger than that on the incidence of unattached unemployment. This study differs from Pissarides (1982) and Mortensen (1990) in that it considers endogenous wage setting obtained by bargaining between workers and firms in the absence of on-the-job search and given a constant recall probability. The new focus of the current study on wage setting in search equilibrium with temporary layoffs permits analysis of an endogenous wage dispersion arising from the differences in outside options of attached and unattached unemployed. In addition, this study allows for agency problems in wage setting such as the limited commitment of workers and firms as well as the two-sided resistance to unfavorable changes of wages.

Wage dispersion is a well studied phenomenon arising in models with on-the-job search. Originally wage dispersion has been documented in the studies of random search with wage posting such as Burdett and Mortensen (1998), Postel-Vinay and Robin (2002b), Burdett and Coles (2003) and Stevens (2004). Burdett and Mortensen (1998) consider wage-posting in a labour market, where firms offering higher wages gain from a reduced quit rate of the worker. In the equilibrium firms are indifferent between offering a low wage and experiencing a high worker turnover versus a high wage and a low worker turnover. This mechanism gives rise to a continuous wage distribution among identical workers and firms. Burdett and Coles (2003) as well as Stevens (2004) extend this approach by allowing firms to post wage-tenure contracts and show that there exists a nondegenerate equilibrium distribution of initial wage offers. A similar result is obtained by Postel-Vinay and Robin (2002b) who construct an equilibrium search model with on-the-job search and allow employers to counter the wage offers received by their employees.

The first attempt to analyze features of a model with on-the-job search and Nash bargaining has been done in Pissarides (1994). However, the simplifying assumption that workers quit their previous job once a match with a new employer is formed does not give rise to the endogenous wage dispersion. Shimer (2006) argues that in a model with on-the-job search and strategic bargaining, the set of feasible payoffs is typically nonconvex because an increase in the wage raises the duration of an employment relationship. He further finds that the subgame perfect equilibrium of such a bargaining model is no longer unique, nevertheless there exist market equilibria with a continuous wage distribution in which identical firms bargain to different wages. Finally, Cahuc, Postel-Vinay and Robin (2006) propose an equilibrium search model with strategic wage bargaining, on-the-job search and counteroffers by competing firms. The cross-sectional distribution of wages is then composed of three components: a worker fixed effect, an employer fixed effect and a random effect, characterizing the most recent wage mobility of the worker. This study differs from the existing literature on wage dispersion in that it does not consider on-the-job search by employed individuals. Instead the focus of the present study is on search-in-attachment by unemployed individuals on a temporary layoff. Thus the endogenous differentiation of unemployed workers into attached and unattached gives rise to a binary equilibrium wage distribution.

### 3 Labour market modeling framework

The labour market is characterized by the following properties. There is a unit mass of infinitely lived workers and an endogenous number of firms. Workers and firms are ex-ante identical, risk neutral and do not have access to credit markets. Both types of agents are assumed to have short memory meaning that they only can keep records of their latest attachment. Firms and workers share a common constant discount factor  $r$ .

There are two types of idiosyncratic productivity shocks in the model. Persistent productivity shocks arrive at the Poisson rate  $\gamma$  and imply a permanent separation between a job and a worker. As a result of the persistent productivity shock the job is permanently destroyed and the worker becomes an unattached unemployed. Temporary productivity shocks arrive with a Poisson arrival rate  $\delta$ . Upon the temporary productivity shock, the productivity variable  $\tilde{y}$  can take one of the two possible realizations  $\{y, y^0\}$  so that the following productivity switching rule applies:

$$\tilde{y} = \begin{cases} y & \text{with probability } p \\ y^0 & \text{with probability } 1 - p \end{cases}$$

where  $y > y^0$  and  $0 \leq p \leq 1$ . The initial productivity of a hired worker is assumed to be high  $\tilde{y} = y$ . When the productivity realization is low  $\tilde{y} = y^0$ , firms have an option to use a temporary layoff, so that each job position can be either filled with a worker and producing output, filled with a worker but neither producing nor searching (temporary layoff) or vacant and searching for a worker. Workers on a temporary layoff are referred to as attached unemployed, while jobs attached to a worker on a temporary layoff are referred to as inactive. Workers on a temporary layoff do not receive wages but are attached to the firm and may be recalled to continue producing.

Independent of the type of unemployment (attached or unattached) workers participate in job search and receive an exogenous flow value of leisure denoted by  $z$ . I assume that search is costless for both types of the unemployed but the cost is prohibitively high for the employed workers so that workers do not search on the job. Searching unemployed workers find a new job with the flow probability  $\lambda(\theta)$ , which is an increasing function of its argument, where  $\theta = v/u$  denotes the market tightness variable,  $u$  – the unemployment rate and  $v$  – the vacancy rate. In contrast to workers, search is costly for firms who pay a constant flow cost of maintaining a vacancy – denoted by  $c$  – and find a worker at the corresponding Poisson arrival rate  $q(\theta) = \lambda(\theta)/\theta$ , decreasing in  $\theta$ .

This follows from the standard assumptions concerning the properties of a matching function: homogeneous of degree one, increasing and concave in both arguments  $u$  and  $v$ .

Wages are determined via the concept of Nash bargaining and there is a single wage to be defined in the contract. Furthermore, it is assumed that a contract can commit the two parties to future payments to be made while the match continues, however either counterparty may terminate the contract at any time, hence contracts are characterized by two-sided limited commitment. In addition, either counterparty has an option but not an obligation to offer, reject or accept the terms for contract renegotiation. This means that contract renegotiations may only take place as a result of a binding participation constraint for either of the contracting parties.

## 4 Search equilibrium with temporary layoffs

### 4.1 Decentralized equilibrium: workers

Suppose first that the necessary condition for the existence of the equilibrium with temporary layoffs is fulfilled, this condition is further derived in section 4.4. Denote  $U$  – surplus of an unattached unemployed worker and  $W^1$  – surplus of a worker employed at wage  $w^1$  (hired from unattached unemployment or recalled). Bellman equations for these two groups of workers are given by:

$$rU = z + \lambda(\theta)(W^1 - U) \quad (4.1)$$

$$rW^1 = w^1 - \delta(1 - p)(W^1 - L) - \gamma(W^1 - U) \quad (4.2)$$

where  $L$  denotes surplus of a worker on a temporary layoff, not producing and searching for a job. Additionally, let  $W^2$  denote surplus of a worker hired from attached unemployment and receiving wage  $w^2$ . Bellman equations for workers in attached unemployment and those who changed the employer can be written as follows:

$$rL = z + \lambda(\theta)(W^2 - L) + \delta p(W^1 - L) - \gamma(L - U) \quad (4.3)$$

$$rW^2 = w^2 - \delta(1 - p)(W^2 - L) - \gamma(W^2 - U) \quad (4.4)$$

The labour market dynamics corresponding to the equilibrium with temporary layoffs is presented in figure 1.

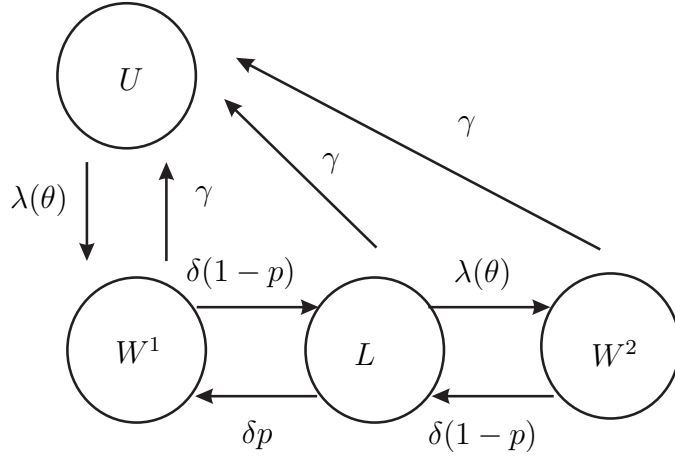


Figure 1: Labour market dynamics

As follows from equation (4.3) surplus value  $L$  can be additionally written as:

$$L = \frac{z + \delta p W^1 + \lambda(\theta) W^2 + \gamma U}{r + \gamma + \delta p + \lambda(\theta)}$$

so that the surplus of an attached unemployed worker is increasing in the probability to find a new job  $\lambda(\theta)$  and in the probability to be recalled back to the previous job  $\delta p$ . Denote  $d_2(\theta) = \lambda(\theta)/(r + \gamma + \delta p + \lambda(\theta))$  – conditional probability to exit the temporary layoff state into a new job, similarly denote  $d_1(\theta) = \delta p/(r + \gamma + \delta p + \lambda(\theta))$  – conditional probability to be recalled to the previous employer and  $d_0(\theta) = r/(r + \gamma + \delta p + \lambda(\theta))$ . Then the surplus value of a worker on a temporary layoff becomes:

$$L - U = d_0(\theta)(Z - U) + d_1(\theta)(W^1 - U) + d_2(\theta)(W^2 - U)$$

where  $Z = z/r$ , which can also be written as:

$$L - U = d_1(\theta)(W^1 - U) + d_2(\theta)\Delta W \quad (4.5)$$

where  $\Delta W = W^2 - W^1$ , since it is true that  $d_0(\theta)(Z - U) + d_2(\theta)(W^1 - U) = 0$ . Note here that  $d_1(\theta)$  is a decreasing function of  $\theta$  and  $d_2(\theta)$  is an increasing function of  $\theta$ . Workers employed from unattached unemployment enter wage negotiations with their employer and obtain wage  $w^1$  with a corresponding surplus value  $W^1$ . Similarly, workers recalled to their previous employer sign a new labour contract but continue receiving wage  $w^1$  since their outside option (unattached unemployment) remains unchanged. Workers employed from attached unemployment enter wage negotiations with their employer and obtain wage  $w^2$  with a corresponding surplus value  $W^2$ . It

is assumed that attachment to a previous employer is destroyed as soon as a labour contract with a new employer is signed, so that every worker can have at most one attachment. This assumption implies that workers who were employed at high wage  $w^2$  but experienced a spell of layoff unemployment obtain a lower wage  $w^1$  after they are recalled.

## 4.2 Decentralized equilibrium: firms

Denote  $J^1$  – surplus of a job paying wage  $w^1$  (filled with a worker from unattached unemployment or recalled). Additionally let  $T$  denote surplus of a job filled with a worker on a temporary layoff. Bellman equations for  $J^1$  and  $T$  can be written as:

$$rJ^1 = y - w^1 - \delta(1 - p)(J^1 - T) - \gamma J^1 \quad (4.6)$$

$$rT = \delta p(J^1 - T) - \lambda(\theta)T - \gamma T \quad (4.7)$$

Surplus value of an inactive firm  $T$  can be expressed in a simplified way:

$$T = d_1(\theta)J^1$$

Finally let  $J^2$  denote surplus of a job filled with a worker from attached unemployment and paying wage  $w^2$ . The Bellman equation for  $J^2$  is given by:

$$rJ^2 = y - w^2 - \delta(1 - p)(J^2 - T) - \gamma J^2 \quad (4.8)$$

which means that firms obtain net flow profits  $y - w^2$  and become inactive at the Poisson arrival rate  $\delta(1 - p)$ .

## 4.3 Wage determination

Both wages  $w^2$  and  $w^1$  are determined via the concept of Nash bargaining. Consider a worker on a temporary layoff negotiating with a new employer. Outside option of such a worker is to remain in attached unemployment and search for another job or to continue producing upon a recall from the previous employer, so that the rent of such a worker is given by  $W^2 - L$ . The rent of a firm negotiating with an attached worker is given by  $J^2 - V$ , where  $V$  denotes surplus of an open vacancy. Wage  $w^2$  is then determined in the following way:

$$\max_{w^2} (W^2 - L)^\beta (J^2 - V)^{1-\beta} \quad (4.9)$$

$$\text{where } W^2 - L = \frac{w^2 - (r + \gamma)L + \gamma U}{r + \gamma + \delta(1 - p)} \quad \text{and} \quad J^2 = \frac{y - w^2 + \delta(1 - p)T}{r + \gamma + \delta(1 - p)}$$

Here  $\beta$  denotes the worker's bargaining power. Firms and workers treat values  $L$  and  $T$  exogenously and in the equilibrium the free entry condition implies  $V = 0$ , this gives rise to the following wage expression:

$$w^2 = \beta[y + \delta(1 - p)T] + (1 - \beta)[(r + \gamma)L - \gamma U] \quad (4.10)$$

Now consider a worker in unattached unemployment negotiating with some employer. Outside option of such a worker is to remain in unattached unemployment, so that the rent of this worker is given by  $W^1 - U$ . The firm rent is given by  $J^1 - V$ . Note that this bargaining problem is the same for a worker on a temporary layoff recalled by his previous employer. The optimization problem is given by:

$$\max_{w^1} (W^1 - U)^\beta (J^1 - V)^{1-\beta} \quad (4.11)$$

$$\text{where } W^1 - U = \frac{w^1 - rU + \delta(1 - p)(L - U)}{r + \gamma + \delta(1 - p)} \quad \text{and} \quad J^1 = \frac{y - w^1 + \delta(1 - p)T}{r + \gamma + \delta(1 - p)}$$

Wage expression resulting from this optimization problem is then:

$$w^1 = \beta[y + \delta(1 - p)T] + (1 - \beta)[rU - \delta(1 - p)(L - U)] \quad (4.12)$$

so that  $w^2 - w^1 = (1 - \beta)(L - U)(r + \gamma + \delta(1 - p))$ . This means that attached unemployed negotiate a higher wage  $w^2 > w^1$  than the unattached due to the fact that  $L > U$  which also means that attached unemployed have a higher reservation wage since they can be recalled to their previous employer. Overall, attached unemployed negotiate a higher wage  $w^2$  with a new employer as opposed to attached unemployed negotiating with their previous employer.

Given the equilibrium wage equations (4.10) and (4.12) the tuple of surplus values  $\{U, T, W^1, W^2, J^1, J^2\}$  can be expressed in terms of the total surplus  $S^1 \equiv J^1 + W^1 - U$  and the total surplus  $S^2 \equiv J^2 + W^2 - L$ :

$$W^1 = U + \beta S^1 \quad J^1 = (1 - \beta)S^1 \quad (4.13)$$

$$rU = z + \lambda(\theta)\beta S^1 \quad T = d_1(\theta)(1 - \beta)S^1 \quad (4.14)$$

$$W^2 = L + \beta S^2 \quad J^2 = (1 - \beta)S^2 \quad (4.15)$$

In addition the surplus value  $L - U$  can be obtained from the following expression:

$$(L - U) = d_1(\theta)\beta S^1 + d_2(\theta)\Delta W$$

This means that a reduced tuple of variables  $\{\theta, S^1, S^2, \Delta W\}$  is now sufficient to characterize surplus values  $\{U, T, W^1, W^2, J^1, J^2\}$ .

#### 4.4 The free-entry condition

Necessary condition for the existence of the equilibrium with temporary layoffs requires rents from a potential wage renegotiation to be negative, meaning that the productivity value  $y^0$  should be sufficiently low. Otherwise workers and firms would benefit from sharing positive rents from renegotiation and continuing the production process. To sum up, workers and firms separate upon a negative productivity shock, if the continuation surplus is lower than the total surplus of a temporary layoff:

$$\frac{\bar{y}^0 - rU}{r + \gamma} \leq T + L - U \quad \text{where} \quad \bar{y}^0 = y^0 + \frac{\delta p \Delta y}{r + \gamma + \delta} \quad (4.16)$$

$$\Leftrightarrow y^0 \leq y - \frac{y - [rU + (r + \gamma)(T + L - U)]}{r + \gamma + \delta(1 - p)}(r + \gamma + \delta) \equiv y_*^0 \quad (4.17)$$

where the left-hand side of inequality (4.16) stands for the surplus from continued production, while the right-hand side is the surplus from temporary separation. Equation (4.17) implies that the productivity value  $y^0$  should be low enough for the rent from renegotiation to be negative. The equilibrium with an expectation of wage renegotiation is described in the next section.

Now assume that condition (4.17) is fulfilled, this case gives rise to the equilibrium with temporary layoffs and between-job wage dispersion. Denote  $\alpha$  – probability for a vacant job to be contacted by an unattached unemployed, so that  $1 - \alpha$  is the probability for a vacant job to be contacted by an attached unemployed. These probabilities can be found as:

$$\alpha = \frac{u_1}{u_1 + u_2} \quad \text{and} \quad 1 - \alpha = \frac{u_2}{u_1 + u_2}$$

where  $u_1$  denotes a share of unattached unemployed workers in the economy and  $u_2$  denotes a share of the attached unemployed. Then the surplus of a vacant job paying

the flow cost  $c$  can be written as follows:

$$rV = -c + q(\theta)(\alpha J^1 + (1 - \alpha)J^2) \quad (4.18)$$

In the equilibrium it should hold that  $V = 0$ , then equation (4.18) becomes:

$$\frac{c}{q(\theta)} = \alpha J^1 + (1 - \alpha)J^2 \quad (4.19)$$

This means that the expected cost from an open vacancy should be equal to the expected firm surplus from a filled job. Denote  $e_1$  – share of workers employed at wage  $w^1$  and  $e_2$  – share of workers employed at wage  $w^2$ . Given that the total labour force is normalized to 1 it holds that  $u_1 + u_2 + e_1 + e_2 = 1$ . Flow transition rates between the four groups of workers are presented in table 2.

Table 2: Flow transition rates between states

State	$u_1$	$u_2$	$e_1$	$e_2$
$u_1$	–	–	$\lambda(\theta)$	–
$u_2$	$\gamma$	–	$\delta p$	$\lambda(\theta)$
$e_1$	$\gamma$	$\delta(1 - p)$	–	–
$e_2$	$\gamma$	$\delta(1 - p)$	–	–

These transition rates correspond to the following system of differential equations in variables  $u_1, u_2, e_1$  and  $e_2$ :

$$\begin{cases} \dot{u}_2 = \delta(1 - p)(e_1 + e_2) - \delta p u_2 - \lambda(\theta)u_2 - \gamma u_2 \\ \dot{e}_1 = \lambda(\theta)u_1 + \delta p u_2 - \delta(1 - p)e_1 - \gamma e_1 \\ \dot{e}_2 = \lambda(\theta)u_2 - \delta(1 - p)e_2 - \gamma e_2 \\ u_1 = 1 - u_2 - e_1 - e_2 \end{cases} \quad (4.20)$$

Each of the equations above implies, that change in a given state variable is equal to the inflow of workers into the state minus the outflow of workers. The unique stable stationary solution with  $\dot{u}_2 = 0$ ,  $\dot{e}_1 = 0$  and  $\dot{e}_2 = 0$  is then:

$$u_1 = \frac{\gamma}{\gamma + \lambda(\theta)} \quad u_2 = \frac{\delta(1 - p)}{\gamma + \delta + \lambda(\theta)} \cdot \frac{\lambda(\theta)}{\gamma + \lambda(\theta)} \quad (4.21)$$

$$e \equiv e_1 + e_2 = \frac{\gamma + \delta p + \lambda(\theta)}{\gamma + \delta + \lambda(\theta)} \cdot \frac{\lambda(\theta)}{\gamma + \lambda(\theta)} \quad (4.22)$$

This means that the probability for a firm to contact an unattached unemployed is:

$$\frac{1 - \alpha}{\alpha} = \frac{u_2}{u_1} = \frac{\lambda(\theta)\delta(1 - p)}{\gamma(\gamma + \delta + \lambda(\theta))} \quad (4.23)$$

Probability  $\alpha$  is a decreasing function of the market tightness  $\theta$ . This means that a higher job-finding rate  $\lambda(\theta)$  reduces the number of unattached unemployed and therefore also the probability for a firm to contact an unattached worker.

To simplify the following representation of the model, denote  $s(\theta) = \gamma + \delta(1 - p)(1 - d_1(\theta))$  – endogenous job separation rate in the model. Job separations are due to a permanent productivity shock arriving at rate  $\gamma$  or due to a temporary productivity shock arriving at rate  $\delta(1 - p)$ . In the state of a temporary layoff workers are not available for a recall with a probability  $(1 - d_1(\theta))$ , so that the total separation rate becomes:  $s(\theta) = \gamma + \delta(1 - p)(1 - d_1(\theta))$ . The job separation rate is an increasing function of  $\theta$ , since a higher probability of finding an external job for a worker on a temporary layoff reduces the probability, that the worker is still available for a recall  $d_1(\theta)$ . Using the definition of  $s(\theta)$ , surplus value  $S^1 = J^1 + W^1 - U$  can be written as:

$$S^1 = J^1 + W^1 - U = \frac{y - w^1}{r + s(\theta)} + \frac{w^1 - rU + d_2(\theta)\Delta W}{r + s(\theta)} = \frac{y - rU + d_2(\theta)\Delta W}{r + s(\theta)}$$

The resulting equilibrium with temporary layoffs is characterized in proposition 1.

**Proposition 1:** *In the presence of negative rents from renegotiation, the layoff risk is realized, the equilibrium is characterized by between-job wage dispersion and is represented by a reduced tuple of variables  $\{\alpha, \theta, S^1, S^2, \Delta W\}$ , satisfying equation (4.23), equations (a)-(c) below as well as the free-entry condition (d). The necessary condition for the equilibrium existence is  $y^0 \leq y_*^0$ .*

(a.) *The total surplus value  $S^2$  is given by:*

$$S^2 = S^1(1 - d_1(\theta)\beta) - d_2(\theta)\Delta W$$

(b.) *The total surplus  $S^1$  is given by:*

$$S^1 = \frac{y - z + c\theta + \delta(1 - p)d_2(\theta)\Delta W}{r + \lambda(\theta) + s(\theta)}$$

(c.) *The surplus difference  $\Delta W$  is given by:*

$$\Delta W = \frac{(1 - \beta)d_1(\theta)\beta S^1}{1 - (1 - \beta)d_2(\theta)} \quad (4.24)$$

(d.) *The free-entry condition defines  $\theta$ :*

$$\frac{c}{q(\theta)} = (1 - \beta)S^1 \left[ 1 - \frac{(1 - \alpha)d_1(\theta)\beta}{1 - (1 - \beta)d_2(\theta)} \right] \quad (4.25)$$

**Proof:** Appendix I.

The free entry condition (4.25) equates expected costs from creating a vacancy on the left-hand side to the expected surplus of a filled job on the right-hand side. Note that in the absence of worker-firm attachment the probability for the firm to contact an unattached worker is  $\alpha = 1$ , so that the right-hand side of equation (4.25) is simplified to  $(1 - \beta)S^1$ , which means, that firms obtain a surplus share  $(1 - \beta)$  of the total job surplus  $S^1$ . For  $0 < \alpha < 1$  expression in square brackets in (4.25) is strictly smaller than 1, which means that the expected firm surplus is less than  $(1 - \beta)S^1$ . This is due to the fact that firms hiring attached unemployed have to pay a higher wage  $w^2$ .

Also note that wage dispersion in the model is a consequence of the interior value of the bargaining power  $0 < \beta < 1$ . As follows from (4.24)  $\beta = 0$  implies  $w^1 = w^2 = rU$  due to the fact that  $U = L = W^1$ , so that neither employment, nor an attachment to the previous employer is valuable for the worker. For  $\beta = 1$  the situation is similar in that  $w^1 = w^2 = y + \delta(1 - p)T$ , so that workers obtain the full maximum rent of the job and do not profit from an additional attachment.

The final step to characterize the model with temporary layoffs is to describe the properties of the Beveridge curve. The market tightness variable is defined as  $\theta = v/u$ , where  $u = u_1 + u_2$  – total unemployment rate in the economy. This means that equations (4.21) define an implicit functional relationship between the number of open vacancies  $v$  and the equilibrium unemployment  $u$  – the Beveridge curve:

$$u = u_1 + u_2 = \frac{\gamma}{\gamma + \lambda(\theta)} \left[ 1 + \frac{\delta(1 - p)\lambda(\theta)}{\gamma(\gamma + \delta + \lambda(\theta))} \right], \quad \text{where } \theta = v/u$$

**Proposition 2:** *In the equilibrium with temporary layoffs and incomplete worker attachment, the Beveridge curve is downward-sloping, in particular  $\partial u/\partial v < 0$  under the assumption that  $\eta_q < 1$ , where*

$$\eta_q = -\frac{\partial q(\theta)}{\partial \theta} \frac{\theta}{q(\theta)} \quad - \text{elasticity of the job filling rate } q(\theta)$$

**Proof:** Denote  $\mu_\theta$  – elasticity of the unemployment rate with respect to  $\theta$ :

$$\mu_\theta \equiv -\frac{\partial u}{\partial \theta} \frac{\theta}{u}$$

Appendix II shows that  $0 < \mu_\theta < 1$  if  $\eta_q < 1$ . Additionally, the elasticity of the Beveridge curve can be expressed as:

$$\frac{\partial u}{\partial v} \theta = -\frac{\mu_\theta}{1 - \mu_\theta} < 0$$

This means that a higher market tightness  $\theta$  is associated with a higher number of open vacancies  $v$  and a lower unemployment rate  $u$ .

## 5 Wage renegotiation in the presence of layoff risk

If condition (4.16) is violated, labour contracts are renegotiated upon a negative productivity shock. This section characterizes an equilibrium with wage renegotiations. Denote  $w^L$  – new wage negotiated between the worker and the firm in the low productivity state. Similarly denote  $w^H$  – initial wage negotiated between a firm and a worker upon hiring in the expectation of wage renegotiation. The corresponding firm and worker surplus values are denoted  $J^H$  and  $W^H$  respectively. After the first production spell workers and firms bargain over a new wage  $w^L$  with the corresponding surplus values  $J^L$  and  $W^L$ :

$$\begin{aligned} (r + \gamma)J^L &= \bar{y}^0 - w^L \\ (r + \gamma)(W^L - U) &= w^L - rU \end{aligned}$$

Note that wage  $w^L$  applies till the end of the employment relationship (including periods of high and low productivity) since worker's threat to quit a productive firm into unemployment is not credible. Outside options of a worker-firm pair are given by  $T$

and  $L$ , so that the Nash-bargaining problem over  $w^L$  becomes:

$$\max_{w^L} (W^L - L)^\beta (J^L - T)^{1-\beta}$$

$$\text{and } w^L = \beta[\bar{y}^0 - rU - (T + L - U)(r + \gamma)] + (r + \gamma)(L - U) + rU \quad (5.1)$$

where the outside option values  $T$  and  $L$  can be obtained as:

$$T = d_1(\theta)J^H \quad (L - U) = \frac{d_1(\theta)(W^H - U)}{1 - (1 - \beta)d_2(\theta)} \quad (5.2)$$

Above expression for  $w^L$  is an optimal solution to the Nash bargaining problem between the firm and the worker as long as equation (4.16) is violated, meaning that the total surplus from a layoff  $T + L - U$  is sufficiently low:  $(T + L - U)(r + \gamma) \leq \bar{y}^0 - rU$ . Bellman equations for  $W^H$  and  $J^H$  are then:

$$\begin{aligned} rW^H &= w^H - \delta(1 - p)(W^H - W^L) - \gamma(W^H - U) \\ rJ^H &= y - w^H - \delta(1 - p)(J^H - J^L) - \gamma J^H \end{aligned}$$

so that the surplus values  $W^H - U$  and  $J^H$  can be expressed as:

$$\begin{aligned} (r + \gamma + \delta(1 - p))(W^H - U) &= w^H - rU + \delta(1 - p)(W^L - U) \\ (r + \gamma + \delta(1 - p))J^H &= y - w^H + \delta(1 - p)J^L \end{aligned}$$

The Nash bargaining problem over  $w^H$  can be summarized as follows:

$$\max_{w^H} (W^H - U)^\beta (J^H - V)^{1-\beta}$$

Given that in the equilibrium  $V = 0$  expression for  $w^H$  takes the following form:

$$\begin{aligned} w^H &= \beta[y + \delta(1 - p)J^L] + (1 - \beta)[rU - \delta(1 - p)(W^L - U)] \\ &= \beta[y + \delta(1 - p)T] + (1 - \beta)[rU - \delta(1 - p)(L - U)] \end{aligned} \quad (5.3)$$

The functional form of  $w^H$  exactly coincides with the functional form of  $w^L$ , this is due to the fact that the net surplus in the low output state  $W^L - L + J^L - T$  is split in the proportion  $\beta$ :

$$\beta(J^L - T) = (1 - \beta)(W^L - L) \quad (5.4)$$

so that the initial labour contract is exactly the same *ceteris paribus* regardless of whether wage negotiations will take place in the future or not. Nevertheless surplus

values  $W^H$  and  $J^H$  are such that  $W^H \geq W^1$  and  $J^H \geq J^1$  since workers and firms expect to share the rents in the future.

Let  $S^H \equiv J^H + W^H - U$  – total surplus of a new job and  $S^L \equiv J^L + W^L - U$  – total surplus in a low productivity state. Then Nash bargaining implies that:

$$W^H = U + \beta S^H \quad W^L - L = \beta[S^L - (T + L - U)] \quad (5.5)$$

$$J^H = (1 - \beta)S^H \quad J^L - T = (1 - \beta)[S^L - (T + L - U)] \quad (5.6)$$

$$rU = z + \lambda(\theta)\beta S^H \quad (5.7)$$

Equations (5.2) in a combination with (5.5)-(5.7) imply that search equilibrium with wage renegotiation can be summarized as a reduced vector of variables  $\{S^H, S^L, \theta\}$  which is sufficient to characterize surplus values  $\{U, T, L, W^L, J^L, W^H, J^H\}$ . Properties of the equilibrium with wage renegotiation are summarized in proposition 3.

**Proposition 3:** *In the presence of positive rents from renegotiation the equilibrium is characterized by within-job wage dispersion and is represented by a tuple of variables  $\{S^H, S^L, \theta\}$  satisfying conditions (a)-(c). The necessary condition for the equilibrium existence is:  $y^0 \geq y_*^0$ .*

(a.) *The total surplus value  $S^L$  is given by:*

$$S^L = \frac{\bar{y}^0 - rU}{r + \gamma}$$

(b.) *The total surplus value  $S^H$  is given by:*

$$S^H = \frac{\bar{y} - z + c\theta - \delta(1 - p)rU/(r + \gamma)}{(r + \gamma + \delta(1 - p) + \lambda(\theta))}$$

where  $\bar{y} = y + \delta(1 - p)\bar{y}^0/(r + \gamma)$ .

(c.) *The free-entry condition defines  $\theta$ :*

$$\frac{c}{q(\theta)} = (1 - \beta)S^H$$

The above equilibrium is characterized by within-job wage dispersion meaning that workers with the same actual productivity  $y$  may be obtaining different wages  $w^H$  or  $w^L$  depending on the history of their relationship with the employer. Denote  $e_H$

– equilibrium share of workers employed at wage  $w^H$  and  $e_L$  – equilibrium share of workers employed at wage  $w^L$ . In the equilibrium it should be true that  $\dot{e}_H = 0$  and  $\dot{e}_L = 0$ , so

$$\begin{aligned} 0 &= \lambda(\theta)u - (\gamma + \delta(1-p))e_H \\ 0 &= \delta(1-p)e_H - \gamma e_L \end{aligned}$$

**Proposition 4:** *In the presence of layoff risk and positive rents from renegotiation the equilibrium shares of workers employed at wages  $w^H$  and  $w^L$  respectively and the equilibrium unemployment rate are given by:*

$$\begin{aligned} e_H &= \frac{\lambda(\theta)u}{\gamma + \delta(1-p)} & u &= \frac{\gamma}{\gamma + \lambda(\theta)} \\ e_L &= \frac{\delta(1-p)\lambda(\theta)u}{\gamma(\gamma + \delta(1-p))} \end{aligned}$$

Denote  $\alpha_H$  – equilibrium fraction of workers employed at wages  $w^H$ . In the presence of layoff risk and positive rents from renegotiation equilibrium value of  $\alpha_H$  is given by:

$$\alpha_H \equiv \frac{e_H}{e_H + e_L} = \frac{\gamma}{\gamma + \delta(1-p)}$$

The equilibrium fraction  $\alpha_H$  is independent of the market tightness, and only depends on the exact characteristics of the production process  $\gamma$  and  $\delta$ . In the absence of temporary productivity shocks  $\delta = 0$ , all workers obtain the initial wage  $w^H = \beta y + (1 - \beta)rU$ .

## 6 Social welfare and optimal policy

Hosios (1990) and further Pissarides (2000) show, that the Nash wage equation is not likely to internalize search externalities resulting from the dependence of transition probabilities  $\lambda(\theta)$  and  $q(\theta)$  on the tightness of the market. Nevertheless Hosios (1990) proves that search externalities may be internalized, if the following condition is satisfied:  $\beta = \eta_q$ , where  $\eta_q$  – elasticity of the job-filling rate  $q(\theta)$ . This section investigates efficiency properties of the equilibrium with Nash bargaining and temporary layoffs and shows, that the classical Hosios condition is not sufficient for the constrained efficiency of the decentralized equilibrium. To obtain this result, consider the problem of

a social planner, whose objective is to maximize the expected net output per worker:

$$\max_{\theta} \int_0^{\infty} e^{-rt} \left[ y(e_1 + e_2) + z(1 - e_1 - e_2) - c\theta(1 - e_1 - e_2) \right] dt \quad (6.1)$$

The social planner is subject to the same matching constraints as firms and workers, therefore the dynamics of employment and unemployment is the same as in the decentralized equilibrium:

$$\begin{aligned} \dot{u}_2 &= \delta(1 - p)(e_1 + e_2) - \delta p u_2 - \lambda(\theta)u_2 - \gamma u_2 \\ \dot{e}_1 &= \lambda(\theta)(1 - e_1 - e_2 - u_2) + \delta p u_2 - \delta(1 - p)e_1 - \gamma e_1 \\ \dot{e}_2 &= \lambda(\theta)u_2 - \delta(1 - p)e_2 - \gamma e_2 \end{aligned}$$

The social optimum satisfies the following first-order condition:

$$\frac{c}{q(\theta)} = (1 - \eta_q) \frac{y - z + c\theta}{r + \lambda(\theta) + s(\theta)} (1 - (1 - \alpha)d_1(\theta)) \quad (6.2)$$

The derivation of this condition is presented in appendix III. Comparing now the social condition (6.2) and the decentralized free entry condition (4.25) I find that the equilibrium is constrained inefficient. To see this recall that the free-entry condition is obtained from expression:

$$\frac{c}{q(\theta)} = \alpha(1 - \beta)S^1 + (1 - \alpha)(1 - \beta)S^2 \quad (6.3)$$

where  $S^2 = J^2 + W^2 - L$  denotes the total surplus of a match with an attached unemployed:

$$S^2 = S^1 - (L - U) = S^1(1 - d_1(\theta)\beta) - d_2(\theta)\Delta W$$

The equilibrium inefficiency comes from the fact that the firm and an attached unemployed do not internalize the losses imposed on the previous employer of the worker. In particular, the previous employer is losing an option to recall the worker, with a corresponding surplus value  $T$ . The social planner is taking this loss into account, so that  $S^2 = S^1 - (T + L - U) = (1 - d_1(\theta))S^1$  in the optimal planner's solution. This externality imposed on the previous employer of the worker is not accounted for in the bargaining process between the worker and a new employer, so that firms hiring attached unemployed create too many jobs compared to the socially optimal level. These results are summarized in the following proposition.

**Proposition 5:** Let  $\beta = \eta_q < 1$ , then:

- (a). Search equilibrium with temporary layoffs and wage dispersion described in proposition 1 is constrained inefficient;
- (b). The market tightness in the decentralized equilibrium is above the socially optimal level, implying excessive job creation;

**Proof:** The proof of part (b) of the proposition follows from the fact that:

$$\frac{\beta}{1 - (1 - \beta)d_2(\theta)} = \frac{\beta}{\beta + (1 - \beta)(1 - d_2(\theta))} < 1$$

and  $\Delta W > 0$ , so that  $S^1 > (y - z + c\theta)/(r + \lambda(\theta) + s(\theta))$ .

The next question addressed in this section is: which tax policy of the planner can decentralize the efficient labour allocation in the equilibrium? As shown above the main source of the inefficiency of the decentralized equilibrium is surplus loss of the previous employer of the worker resulting from worker's decision to start a new job. Throughout the paper it is assumed, that firms can observe worker's attachment status and so does also the social planner. This means the tax imposed on attached unemployed taking on new employment should restore efficiency of the decentralized equilibrium. Let  $\tau$  denote an income tax imposed on attached unemployed starting job with a new employer and  $s$  – income subsidy for every worker. Bellman equations for  $W^1$ ,  $W^2$ ,  $L$  and  $U$  are then modified in the following way:

$$\begin{aligned} rU &= z + s + \lambda(\theta)(W^1 - U) \\ rW^1 &= w^1 + s - \delta(1 - p)(W^1 - L) - \gamma(W^1 - U) \\ rL &= z + s + \lambda(\theta)(W^2 - L) + \delta p(W^1 - L) - \gamma(L - U) \\ rW^2 &= w^2 - \tau + s - \delta(1 - p)(W^2 - L) - \gamma(W^2 - U) \end{aligned}$$

Then the surplus difference  $\Delta W$  is given by:

$$\Delta W = \frac{w^2 - \tau - w^1}{r + \gamma + \delta(1 - p)} = \frac{\beta[(1 - \beta)d_1(\theta)S^1 - F]}{1 - (1 - \beta)d_2(\theta)} \quad (6.4)$$

where  $F$  denotes the present value of tax payments:  $F = \tau/(r + \gamma + \delta(1 - p))$ . Note that from equation (4.14) it follows that  $T = (1 - \beta)d_1(\theta)S^1$ , where  $T$  is surplus of an inactive firm attached to the worker. This means imposing a tax such that  $T = F$  will

eliminate the real wage inequality:  $w^2 - \tau = w^1$ . The surplus value  $S^2$  becomes:

$$S^2 = S^1 - (L - U) - F = S^1 - (L - U) - T = S^1(1 - d_1(\theta)) \quad (6.5)$$

This equation in a combination with  $\beta = \eta_q$  (to internalize the search externality) guarantees, that the market tightness in the decentralized equilibrium is set optimally, and that job creation coincides with the solution of the social planner. The amount of subsidies  $s$  is then obtained from the balanced budget constraint of the planner:

$$(\tau - s)e_2 = s(e_1 + u_1 + u_2)$$

This means that the total net income flow  $\tau - s$  paid by attached unemployed starting job with a new employer is distributed to the other three groups of workers  $e_1 + u_1 + u_2$ . This result is stated in proposition 6:

**Proposition 6:** *Let  $\beta = \eta_q < 1$ . Welfare in the decentralized equilibrium with temporary layoffs can be raised by imposing a tax  $\tau$  on attached unemployed starting job with a new employer, such that  $F = T = d_1(\theta)(1 - \eta_q)S^1$ . This tax policy eliminates real wage inequality  $w^2 - \tau = w^1$  and is equivalently written as:*

$$F \equiv \frac{\tau}{r + \gamma + \delta(1 - p)} = d_1(\theta)(1 - \eta_q) \frac{y - z + c\theta}{r + s(\theta) + \lambda(\theta)} \quad (6.6)$$

*The balanced budget constraint of the planner implies that taxes are paid out as subsidies  $s$  obtained from:  $s = \tau e_2$ .*

## 7 Empirical estimation

In this section a testable hypothesis based on the theoretical model from section 4 is formulated and confronted with the statistical data. The model predicts that workers on a temporary layoff recalled to the previous employer obtain low wage  $w_{t+1} = w_1$ ; this result endogenously obtains in the model due to the bargaining process between workers and firms since the outside option of a worker bargaining with a previous employer is to become an unattached unemployed. Wage  $w_1$  prevails in this case and is independent of the previous wage of the worker  $w_t$ . In addition, the model allows to formulate an expression for the expected wage of a worker taking job with a new employer. With probability  $\alpha$  the worker is an unattached unemployed and will bargain a wage  $w_1$ , but with probability  $1 - \alpha$  the worker is attached to the previous employer

and has a higher reservation wage, so the contract wage with a new employer will be  $w_2$ . This means that the expected value of wage for a worker taking employment with a new firm is:  $\alpha w_1 + (1 - \alpha)w_2$ . This allows to formulate the following hypothesis:

**Hypothesis:** *For any value of the previous wage  $w_t$  expected wage change  $\Delta w$  of an employee recalled to work for the previous employer is lower than the expected wage change of an employee taking job with a new employer:*

$$\begin{aligned} E_t[\Delta w | Recall_{t+1} = 1] &= E[w_{t+1} | Recall_{t+1} = 1] - w_t = w_1 - w_t \\ E_t[\Delta w | New job_{t+1} = 1] &= \alpha w_1 + (1 - \alpha)w_2 - w_t \geq w_1 - w_t \end{aligned}$$

To estimate the effect of recalls on wage changes I use the data from the German Socio-Economic Panel (GSOEP), a large micro- dataset administered by the Deutsches Institut für Wirtschaftsordnung. The sample covers the period of 5 years from 2003 to 2007 and includes the total of 7328 observations on job movers. The net of missing data sample contains 2595 observations. The wage change  $\Delta w$  is coded in the questionnaire as a dummy variable:

$$y_i = \begin{cases} 1 & \text{if } \Delta w_i = w_{it+1} - w_{it} > 0 \\ 0 & \text{if } \Delta w_i = w_{it+1} - w_{it} \leq 0 \end{cases} \quad (7.7)$$

so that the probit regression model is used to forecast the direction of wage changes. Index  $i = 1, \dots, 2595$  here denotes the observation of wage change, while indices  $t$  and  $t + 1$  are used to mark the previous and the new wage of the employee. The probability of a positive change  $y_i = 1$  is then given by

$$P\{y_i = 1 | X_i\} = P\{\Delta w_i > 0 | X_i\} = \Phi(X_i' \beta) \quad (7.8)$$

where  $\Phi(\cdot)$  is the cumulative density function of the normal distribution,  $\beta$  is the parameter vector and  $X_i$  – is the vector of explanatory variables of individual  $i$ . About 44% of the respondents in the final sample have reported a wage improvement compared to the previous job. Table 3 presents an overview of the explanatory variables. The list of individual characteristics consists of the following variables *Age*, *Education*, *German* and *Gender*. Table 3 shows that the representative employee in the sample is 36 years old and has completed approximately 13 years of schooling, 93.8% of the employees have German nationality and 52.4% of the employees are males. These variables create an overview of the representative individual in the sample, at the same time variables *Education*, *German*, and *Gender* are deterministic for the same indi-

vidual so that their effect on the probability of wage improvement is predicted to be insignificant. A number of empirical studies show that variable *Age* enters quadratically into the wage equation, meaning that wage is increasing with age up to some maximum level and is decreasing thereafter. Variable *Age* for this reason is then predicted to have a negative effect on the probability of wage improvement.

Variable	Mean	Description
<i>Dependent variable</i>		
Pay improved	0.443	1=Earnings have improved in the new job
<i>Individual characteristics</i>		
Age	36.06	Age of the individual in years [18, ..., 68].
Education	12.81	Amount of education or training in years [7, ..., 18]
German	0.938	1=German nationality
Gender	0.524	1=Male
<i>Previous job characteristics</i>		
Tenure	4.625	Number of years with a previous employer [0, ..., 43]
Recall	0.048	1=Returned to the previous employer
<i>Reason for separation</i>		
Quit	0.404	1=Previous employment ended in a quit
Layoff	0.185	1=Previous employment ended in a layoff
Job closure	0.121	1=Previous employment ended due to job closure
Temp. contract	0.164	1=Temporary contract expired
<i>Job comparison</i>		
Promotion	0.330	1=Promotion possibilities have improved in the new job
Benefits	0.228	1=Social benefits provision has improved in the new job
Security	0.262	1=Work security has improved in the new job

Table 3: Explanatory variables

The major variable of interest in this study is *Recall*, this variable takes value 1 if the worker returns to the previous employer, and zero otherwise. In the original sample of 7328 observations recall rate is estimated to be 8.3%, but is reduced to only 4.8% in the final sample. The sign on the regression coefficient of *Recall* should then be negative and significant in order to support the above hypothesis. Variable *Tenure* measures the individual's experience with a previous employer. This variable traditionally has positive effect on wages, but job changes are associated with a loss of the accumulated tenure, so this variable is predicted to have a negative impact on the probability of wage improvement.

The group of variables *Quit*, *Layoff*, *Job closure* and *Temp. contract* are included in order to capture the "gains" from mobility. Note, that these variables are self-reported,

specifically the respondents were asked "How did your previous job end?". Based on this data, quits comprise the largest category and amount to about 40% of the final sample; about 30% of job changes are due to layoffs and job closures and only 16.4% – are due to the end of a fixed-term contract. The omitted variable *Mutual separations* amounts to 12.6% of the sample and serves as a reference category. Variables *Layoff* and *Job closure* capture involuntary separations with a possible spell of involuntary unemployment and are therefore expected to have negative effects. In contrast, variable *Quit* captures voluntary mobility decisions and gains from possible job-to-job transitions; this variables is therefore expected to have a positive effect.

The final group of variables *Promotion*, *Benefits* and *Security* are included into the model to capture qualitative differences between the jobs. 33% of the respondents have obtained a promotion in the new job, while only 23% have obtained additional benefits and 26% have claimed an improved job security. A negative sign of the regression coefficient on each of these variables would imply substitution between wages and the respective job characteristic, while a positive sign implies complementarity.

Probit estimation results are presented in table 4. The second column of this table contains coefficients from the original estimation, while the reduced form regression including only significant variables is presented in the third column of table 4. A lower number of variables allows to increase the number of observations (to 3241) and therefore the precision of the estimated coefficients. The last column of table 4 contains marginal effects of the explanatory variables, which can be interpreted as a change in the probability of wage improvement corresponding to a unit change in the respective explanatory variable. All of the explanatory variables in the sample, except *Age* and *Tenure*, are binary variables, so the change in the probability of wage improvement given a unit change in the explanatory variable  $X_{ij}$  is given by:

$$\Delta P\{y_i = 1|X_0\} = P\{y_i = 1|X_0, X_{ij} = 1\} - P\{y_i = 1|X_0, X_{ij} = 0\} \quad (7.9)$$

where  $X_0$  denotes characteristics of the representative individual:

$$X_0 = \{Age = 36, Recall = 0, Promotion = 0, Benefits = 0, \\ Security = 0, Layoff = 0, Quit = 0, Bankruptcy = 0\}$$

First of all, note that the Likelihood ratio test indicates an overall significance of the probit regression at 1% significance level:  $LR = 528.14$ . Furthermore, variable *Recall*

Table 4: Probit estimation results

Dependent variable $y_i = 1$ if wage improvement in the new job						
Variable	Coefficient	Standard deviation	Reduced form	Standard deviation	Probability change	Standard deviation
Constant	-.059	(.240)	-.030	(.155)		
Age	-.014**	(.006)	-.013**	(.005)	-.005**	(.002)
<i>Previous job characteristics</i>						
Tenure	-.005	(.005)				
<b>Recall</b>	<b>-.288**</b>	(.132)	<b>-.244**</b>	(.110)	<b>-.079**</b>	(.034)
<i>Job comparison</i>						
Promotion	.627**	(.059)	.638**	(.052)	.246**	(.020)
Benefits	.620**	(.067)	.612**	(.059)	.235**	(.024)
Security	.217**	(.064)	.186**	(.057)	.068**	(.021)
<i>Reason for separation</i>						
Quit	.264**	(.084)	.180**	(.057)	.065**	(.021)
Layoff	-.165*	(.098)	-.254**	(.069)	-.082**	(.022)
Job closure	-.266**	(.111)	-.340**	(.090)	-.107**	(.027)
Temp. contract	.091	(.100)				
Observations	2595		3241		3241	
Pseudo $R^2$	0.1482		0.1415			
Log likelihood	-1518.3		-1911.2			

Standard deviations are given in parentheses; Two-tailed significance: \* 10%, \*\* 5%;

Variables *Education*, *German*, *Gender* and year dummy variables are included at the initial stage but not significant at 10% significance level.

is significantly negative, meaning that recall to the job with a previous employer is associated with 7.9% lower probability of wage improvement compared to a job with a new employer. These result supports the hypothesis of worker-firm attachment and its implications for wages suggested in the theoretical part of this paper. To some extent, this result is also anticipated in Burda and Mertens (2001) who have used a merged German data sample from GSOEP and IAB (the social insurance data) to test for sample homogeneity including and excluding recalled individuals. Their findings show that the Chow test consistently rejects homogeneity of the two samples.

Inline with the prediction, variable *Age* has negative effect on the probability of wage improvement for job movers. Age of the individual is often seen as a proxy for the potential experience, and so this finding is in accordance with the existing studies, i.e. for Germany Dustmann and Pereira (2005) have found that "wage gains at job changes... become negative towards the end of individuals' careers." (p.18). A similar finding is reported in Topel and Ward (1992), who find that between-job wage gains decline with

experience in the US.

The coefficient on *Tenure* is negative but not significant, meaning that the loss of job-specific experience does not have effect on the probability of wage improvement. This finding is not unique for Germany, for example, Dustmann and Pereira (2005) find insignificant tenure effect in wage growth regressions; this is however different in the US, where Topel and Ward (1992) report that between-job wage gains decline with prior job tenure. One of the explanations of this difference is presented in Dustmann and Pereira (2005), who attribute the difference to a heavy use of apprenticeship training in Germany as opposed to the US. Apprenticeship training provides job-specific knowledge to workers prior to their first employment and therefore has a flattening effect on the ex-post wage growth of German workers.

Voluntary separations (quits) are associated with about 6.5% higher probability of wage improvement, while involuntary separations reduce this probability by 8.2% in the case of layoff and 10.7% in the case of job closure. At the same separations due to the end of a temporary contract are not significantly different from mutual separations, which are used as a reference category. These results are fully supported in the empirical literature: Mincer (1993) finds that voluntary transitions in the US lead to wage gains of between 10% and 20%, while Bartel and Borjas (1981) find that layoffs reduce wage growth over the two-year period by about 19 cents per hour. For Germany Burda and Mertens (2001) find that full-time men displaced in 1986 and subsequently reemployed in 1987 suffer a reduction of wage growth of about 3.6% when compared with a reference group of continuously employed workers. Garcia-Perez and Rebollo-Sanz (2005) find that German workers tend to experience larger wage losses compared to the rest of countries, around 22%, followed by French, Spanish and Portuguese workers, who suffer wage losses of 14%, 10% and 9% respectively. Moreover, Garcia-Perez and Rebollo-Sanz (2005) report that in France, Germany and Portugal voluntary movers experience a small but positive return when changing jobs of around, 1% in France, 2% in Germany and 4% in Portugal.

Finally, variables *Promotion*, *Benefits* and *Security* have strong positive effects on the probability of wage improvement. In particular, job promotion is associated with 24.6% higher probability of wage improvement, followed by 23.5% increase for additional benefits and 6.8% increase for the improved job security. Table 7 shows empirical correlations of wages with the additional benefits paid in Germany in 2003:

13th Month Pay	0.44
14th Month Pay	0.19
Christmas Bonus	0.19
Vacation Bonus	0.23
Profit-sharing Bonus	0.32

Table 5: Correlations between benefit payments and wages.

All of the benefit variables are positively associated with wages, in particular, strongest correlations are attained for the 13th month pay (0.44) and for the profit-sharing bonus payment (0.32). For a more detailed theoretical treatment of the correlation between wages and bonus payments see Chizhova (2008). These findings indicate strong complementarity between wages and other benefits in Germany, rather than substitution, and mean that firms paying higher wages also tend to provide higher benefits, better promotion possibilities and improved job security to the workers. For the theoretical explanation of the complementarity effect between wages and job security see Chizhova (2007).

## 8 Conclusions

This paper develops a search model with stochastic idiosyncratic productivity shocks and worker-firm attachments. The possibility to recall the previous attachment as well as the temporary nature of productivity fluctuations mutually motivate existence of temporary layoffs in the equilibrium. This equilibrium obtains for large productivity fluctuations, sufficient to induce a temporary separation, otherwise mutual agreement on wage reduction between workers and firms eliminates the necessity for a layoff. In the equilibrium with temporary layoffs attachment is incomplete implying that workers search for better job alternatives during the low productivity spells. Ex-post differentiation of unemployed workers into attached and unattached combined with Nash bargaining produces a binary equilibrium wage dispersion. Here attached unemployed bargain higher wages upon a match with a new employer as opposed to the unattached unemployed. So the paper contributes to the debate on endogenous wage dispersion.

Furthermore, this paper investigates welfare properties of the decentralized equilibrium with temporary layoffs by comparing it to the solution of the utilitarian social planner. As a result, the Hosios value of the bargaining power parameter does not

any longer provide the constrained efficiency. The new type of the inefficiency in the model is explained by the fact, that workers bargaining with a new firm impose a negative externality on their previous employer, who is losing a valuable option to recall the employee upon a good productivity realization. This attachment externality is complementary to the classical search externality described in Hosios (1990). In order to separate the two effects I set the bargaining power parameter equal to the elasticity of the job filling rate and show, that job creation is excessive in the decentralized equilibrium with temporary layoffs. Efficiency may be restored by imposing a tax on firms hiring workers from attached unemployment.

Finally, theoretical implications of the model are tested against the empirical data using the German Social Economic Panel for the years 2003-2007. The probit regression for wage gains shows that recalls have significant impact on future wage changes of workers. In particular, being recalled to the previous employer is associated with approximately 8% lower probability of wage improvement. This means that worker-firm attachment and recalls provide an additional explanation of the observed wage heterogeneity in Germany. Other significant variables employed in the estimation include the reason for separation and job comparison variables. This paper shows that being laid off from the previous job imposes 8.2% lower probability of wage improvement, while voluntary separations (quits) increase this probability by 6.5%. Moreover, additional benefits, better promotion possibilities and improvements in the job security act as complements to wage gains.

## 9 Appendix

### Appendix I: Proof of proposition 1.

The worker surplus  $W^1 - U$  can be written in the following way:

$$W^1 - U = \frac{w^1 - z + \delta(1-p)(L - U)}{r + \gamma + \delta(1-p) + \lambda(\theta)}$$

since  $rU = z + \lambda(\theta)(W^1 - U)$ . Additionally, the firm surplus is:

$$J^1 = \frac{y - w^1 + c\theta + \delta(1-p)T}{r + \gamma + \delta(1-p) + \lambda(\theta)}$$

this allows to obtain the value of  $S^1$  since  $S^1 = J^1 + W^1 - U$ . Additionally it is true that  $T + L - U = d_1(\theta)S^1 + d_2(\theta)\Delta W$ , then the total surplus  $S^1$  becomes:

$$S^1 = \frac{y - z + c\theta + \delta(1 - p)d_2(\theta)\Delta W}{r + s(\theta) + \lambda(\theta)}$$

Now rewrite the free-entry condition (4.19) in the following way:

$$\frac{c}{q(\theta)} = \alpha(1 - \beta)S^1 + (1 - \alpha)(1 - \beta)S^2$$

where

$$S^2 = S^1 - (L - U) = S^1(1 - d_1(\theta)\beta) - d_2(\theta)\Delta W$$

From the wage setting equations (4.12), (4.10) it follows that:

$$\Delta W = \frac{w^2 - w^1}{r + \gamma + \delta(1 - p)} = (1 - \beta)(L - U)$$

which allows to rewrite the surplus difference  $\Delta W$  in the following way:

$$\Delta W = \frac{(1 - \beta)d_1(\theta)\beta S^1}{1 - (1 - \beta)d_2(\theta)}$$

so that the free-entry condition becomes:

$$\begin{aligned} \frac{c}{q(\theta)} &= (1 - \beta)[\alpha S^1 + (1 - \alpha)S^2] \\ &= (1 - \beta)S^1 \left[ \alpha + (1 - \alpha) \left[ 1 - d_1(\theta)\beta - d_2(\theta) \frac{(1 - \beta)d_1(\theta)\beta}{1 - (1 - \beta)d_2(\theta)} \right] \right] \\ &= (1 - \beta)S^1 \left[ 1 - \frac{(1 - \alpha)d_1(\theta)\beta}{1 - (1 - \beta)d_2(\theta)} \right] \end{aligned}$$

## Appendix II: Proof of proposition 2.

The elasticity variable  $\mu_\theta$  can be expressed as follows:

$$\mu_\theta = [1 - \eta_q] \frac{\lambda(\theta)}{\gamma + \lambda(\theta)} k(\theta) < 1, \quad \text{where}$$

$$k(\theta) = \frac{\gamma(\gamma + \delta p + \lambda(\theta)) + \delta(1 - p)(\gamma + \lambda(\theta)) \frac{\lambda(\theta)}{\gamma + \delta + \lambda(\theta)}}{\gamma(\gamma + \delta p + \lambda(\theta)) + \delta(1 - p)(\gamma + \lambda(\theta))} < 1$$

### Appendix III: Social Planner

The current value Hamiltonian for the social planner problem is:

$$\begin{aligned}
H &= y(e_1 + e_2) + z(1 - e_1 - e_2) - c\theta(1 - e_1 - e_2) \\
&+ \mu_1 \left[ \delta(1 - p)(e_1 + e_2) - \delta p u_1 - \lambda(\theta)u_1 - \gamma u_1 \right] \\
&+ \mu_2 \left[ \lambda(\theta)(1 - e_1 - e_2 - u_1) + \delta p u_1 - \delta(1 - p)e_1 - \gamma e_1 \right] \\
&+ \mu_3 \left[ \lambda(\theta)u_1 - \delta(1 - p)e_2 - \gamma e_2 \right]
\end{aligned}$$

where  $\mu_1$ ,  $\mu_2$ , and  $\mu_3$  are costate variables corresponding to  $u_1$ ,  $e_1$ , and  $e_2$  respectively.

The optimal social planner solution must satisfy:

$$\begin{aligned}
\frac{\partial H}{\partial \theta} &= 0 \Rightarrow -(1 - e_1 - e_2)c = \\
&= \left[ \mu_1 u_1 - \mu_2(1 - e_1 - e_2 - u_1) - \mu_3 u_1 \right] \lambda'(\theta) \tag{9.1}
\end{aligned}$$

$$\begin{aligned}
\frac{\partial H}{\partial u_1} &= r\mu_1 \Rightarrow -\mu_1(\delta p + \lambda(\theta) + \gamma) + \mu_2(\lambda(\theta) + \delta p) = \\
&= \mu_3 \lambda(\theta) + r\mu_1 \tag{9.2}
\end{aligned}$$

$$\begin{aligned}
\frac{\partial H}{\partial e_1} &= r\mu_2 \Rightarrow y - z + c\theta + \mu_1 \delta(1 - p) - \mu_2 \lambda(\theta) = \\
&= \mu_2(\delta(1 - p) + \gamma) + r\mu_2 \tag{9.3}
\end{aligned}$$

$$\begin{aligned}
\frac{\partial H}{\partial e_2} &= r\mu_3 \Rightarrow y - z + c\theta + \mu_1 \delta(1 - p) - \mu_2 \lambda(\theta) = \\
&= \mu_3(\delta(1 - p) + \gamma) + r\mu_3 \tag{9.4}
\end{aligned}$$

From equations (9.3)-(9.4) it follows that  $\mu_2 = \mu_3$ , then from equations (9.1), (9.3) it is true that:

$$\begin{aligned}
\frac{c}{q(\theta)} &= (1 - \eta_q) \left[ (1 - \alpha)(\mu_2 - \mu_1) + \alpha \mu_2 \right] \\
y - z + c\theta &= \mu_2(r + \gamma + \lambda(\theta)) - (\mu_1 - \mu_2)\delta(1 - p)
\end{aligned}$$

where  $\alpha = u/(u + u_1)$ . From equation (9.2) it follows that  $\mu_1 = d_1(\theta)\mu_2$ , so

$$\mu_2 = \frac{y - z + c\theta}{r + \lambda(\theta) + s(\theta)}$$

Finally, the optimal market tightness is obtained from:

$$\frac{c}{q(\theta)} = (1 - \eta_q) \frac{y - z + c\theta}{r + \lambda(\theta) + s(\theta)} (1 - (1 - \alpha)d_1(\theta))$$

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