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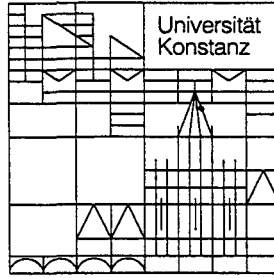
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## **Fakultät für Wirtschaftswissenschaften und Statistik**

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### **Efficiency-Wage Unemployment and Endogenous Growth**

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Diskussionsbeiträge

**Efficiency-Wage Unemployment and  
Endogenous Growth**

**Jürgen Meckl**

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# Efficiency–Wage Unemployment and Endogenous Growth

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## Abstract

This paper examines positive and normative implications of efficiency–wage induced unemployment within a model of endogenous growth. Sector-specific impacts of the wage rate on labor efficiency establish a correlation between the growth rate and the rate of unemployment. The sign of this correlation is shown to be given by the intersectoral wage differential. Despite the existence of unemployment, decisive positive properties of the full-employment model are preserved. However, welfare implications of the full-employment model may be reversed. The optimal policy can be to reduce growth, while at the same time raising unemployment.

JEL Classification: E24, O40

Keywords: Innovation-based growth, unemployment, efficiency wages

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# 1 Introduction

The slowdown in economic growth in the 1970s and early 1980s went hand in hand with a persistent rise in unemployment rates in many industrialized countries. Thus, it comes at no surprise that policies promoting economic growth are also thought to be appropriate measures for reducing unemployment. Taking this favorable effect for granted, growth-augmenting measures are widely judged as beneficial for society. The present paper argues that this reasoning may be based on two fallacies. First, from a positive point of view, it is by no means clear whether augmenting economic growth actually lowers unemployment. Second, from a normative perspective, policies promoting growth can reduce welfare even if there is a negative correlation between growth and unemployment. The optimal policy may well be a policy that hinders growth and at the same time drives up unemployment.

The theoretical interest in the examination of the growth-unemployment trade off is just in its infancy. Bean and Pissarides (1993), Aghion and Howitt (1994), and Ramser (1997) cast doubts on the conjectured negative correlation between growth and unemployment, doubts which are confirmed by the empirical results in Bean and Pissarides (1993) and Caballero (1993). These theoretical analyses are all based on the matching approach thus concentrating on search (frictional) unemployment. But the matching approach can by no means be considered to offer a fully comprehensive explanation of existing unemployment. Furthermore, models based on the matching approach are not able to account for the stability of non-competitive intersectoral wage differentials, a fact that has been emphasized in the empirical labor-market literature (cf. Krüger and Summers 1988, Katz and Summers 1989). The present paper draws on efficiency wages as an alternative explanation of unemployment. The specific approach we employ is compatible with stable intersectoral wage differentials. The theoretical analysis implies that, in general, the correlation between the rate of growth and the rate of unemployment is ambiguous. More specifically, we show that the sign of this correlation is related to the sign of the wage differentials. Thus, the actual correlation between growth and unemployment can easily be substantiated by empirical examination.

Subsequently, we incorporate efficiency-wage unemployment into a model of innovation-based growth along the lines of Romer (1990) and Grossman and Helpman (1991). In this framework, growth is brought about by technical progress

taking the form of an expansion of product varieties that serve as intermediate inputs in the production of final goods. Specifically, we employ a slightly modified version of the Romer model as presented in Barro and Sala-i-Martin (1995: ch. 6). The efficiency-wage approach we use is an extension of Solow's (1979) model that has been developed in Albert and Meckl (1998, 1999). We assume that labor productivity depends on the wage paid by the firm relative to average labor income across the economy. As argued by Albert and Meckl, a relation between relative wages and productivity can be based on fairness considerations affecting the motivation of workers. Given intersectoral differences in the wage-productivity relation, we can explain both positive rates of unemployment and stable intersectoral wage differentials while preserving decisive properties of the original Romer approach. In particular, the dynamics of the model are shown to be formally identical to the full-employment model. However, the welfare properties differ between the full-employment and the unemployment version of the model. As we will show, policies have two effects on welfare which may counteract. First, there is a welfare gain of higher growth resulting from internalizing the intertemporal spillover effects from innovation. This effect is well known from the full-employment model (cf. Barro and Sala-i-Martin 1995: 229). Second, welfare is affected by the change in aggregate employment. Aggregate employment affects the utility of households via the disutility of effort and the disutility of being unemployed. The relation between aggregate employment and these disutilities will turn out to be ambiguous. This implies that a rise in aggregate employment can actually lower welfare. Furthermore, since there are no restrictions concerning the magnitude of the welfare impact from changes in aggregate employment, a welfare loss from changes in aggregate employment may well dominate the welfare gain from higher growth. Hence, a policy promoting growth and aggregate employment may lower aggregate welfare.

The present paper relates most closely to the line of research started by Van Schaik and De Groot (1998) and Stadler (1998). These authors also develop models of endogenous growth where efficiency-wage unemployment occurs because effort in a sector is positively related to the relative wage of that sector. However, both papers assume the existence of a secondary labor market where wages have no effect on labor productivity. In order to prevent labor market clearing by this secondary market (as, e.g., in the dual-labor-market model of

Katz and Summers 1989), they assume that once workers accept employment in the secondary labor market, they cannot apply for jobs in the primary labor market any more. Consequently, these models do not explain involuntary unemployment. Workers are unwilling to accept a reduction of secondary-sector wages in order to become employed there. However, this behavior is completely rational, since the expected wage in the primary sector equals the wage rate in the secondary sector. Another weakness of these models is that labor—although homogeneous *ex ante*—is not homogeneous *ex post*. It follows that they cannot explain intersectoral wage differentials for homogeneous labor as they are observed by empirical studies. Eventually, both models lack a correct microfoundation of consumer behavior (cf. section 2, fn. 2) which makes a discussion of welfare effects impossible. The present paper overcomes these problems. Our explanation of intersectoral wage differentials does not draw on a secondary labor market where there is no incentive–wage problem, but from intersectoral differences in the productivity–wage nexus. This allows us to preserve the homogeneity of labor and to explain involuntary unemployment. Additionally, our analysis is based on a fully microeconomically founded approach.

The paper is organized as follows. Section 2 presents the model and derives the equilibrium rates of growth and unemployment. Positive and normative effects of policies that have been suggested in the literature for promoting growth and/or reducing unemployment are discussed in section 3. Section 4 concludes.

## 2 The model

### 2.1 Consumer sector

We assume that employed workers derive utility from consumption and disutility from effort at work. Unemployed workers derive utility from consumption and exert no effort. However, it is often argued that there is a disutility stemming from the state of being unemployed as such (cf. Oswald 1997, Winkelmann and Winkelmann 1998). We will account for this kind of disutility in our model.

The individual and aggregate labor supply is fixed; workers, if they are not unemployed, can only adjust their effort. The basis of our version of efficiency wages is the idea of Akerlof and Yellen (cf. Akerlof 1982, Akerlof and Yellen 1990) that firm and workers implicitly exchange gifts: If firms set higher wages

in relation to some reference wage, workers reciprocate with higher effort. The source of this behavior is that workers respect a fairness norm. We assume that the effort  $\epsilon$  required by the fairness norm depends on the employer's wage offer  $w$  and average labor income  $\bar{w}$ .<sup>1</sup> Thus workers, in determining how much effort is required by fairness considerations, compare their wage with the average labor income in the economy, including the labor income of the unemployed. The latter is assumed to be zero here. Average labor income then is

$$\bar{w} = \frac{\sum_i w_i L_i}{L}, \quad (1)$$

where  $w_i$  is the wage paid by firms in sector  $i$ ,  $L_i$  is employment in that sector, and  $L$  is total labor supply. We will refer to  $\bar{w}$  as the reference wage. The reference wage is equal to the expected labor income of a worker drawn randomly from the population. Labor-market conditions affect the reference wage through the proportion of workers receiving no labor income.

On a technical level, we assume

$$\epsilon = \epsilon(w/\bar{w}), \quad \epsilon'(\cdot) > 0.$$

The function  $\epsilon(w/\bar{w})$  is called the effort function. There is no clear economic intuition concerning the properties of an effort function. At least for some relevant range, any weakly increasing function seems acceptable. We will simplify matters and assume that the effort function is affine:

$$\epsilon(w/\bar{w}) = a + bw/\bar{w}, \quad a \geq 0, b > 0. \quad (2)$$

We further simplify the model by assuming separation properties of the utility function and risk neutrality. Specifically, instantaneous utility is given by

$$u = \begin{cases} c - a - bw/\bar{w} & \text{for an employed worker} \\ c - z & \text{for an unemployed worker,} \end{cases}$$

where  $c$  denotes individual consumption, and  $z \geq 0$  is the disutility from unemployment. We assume that utility functions of all workers are identical.

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<sup>1</sup>In contrast to the Akerlof-Yellen approach, in our model the standard of fairness is not provided by intra-firm comparisons with other factor prices, but—as in Summers (1989)—by the workers own opportunities outside the firm.



Our assumptions allow for aggregation over employed and unemployed workers without having to account for risk considerations.<sup>2</sup> This allows for modelling the consumer side by a representative agent solving the following intertemporal maximization problem:

$$\begin{aligned} \max_C \int_t^\infty \left[ C - \sum_i L_i (a + bw_i/\bar{w}) - z \left( L - \sum_i L_i \right) \right] e^{-\rho(\tau-t)} d\tau \quad (3) \\ \text{s.t. : } \dot{W} = rW + \sum_i w_i L_i - C, \end{aligned}$$

where  $C$  denotes aggregate consumption,  $\rho$  represents the subjective discount rate,  $W$  is the representative agent's stock of assets, and  $r$  is the interest rate. Implicitly, we treat the consumption good as numeraire. Note that utility is affected by the allocation of labor across sectors. Individuals, however, cannot decide on this allocation. The first order conditions of this problem require that  $r(t) = \rho$  for all  $t$ . The linearity of preferences imply that the interest rate is determined by the decisions of households.

## 2.2 Production sector

The production side of the economy consists of three sectors: a final-goods sector, an intermediate-goods sector, and a research sector. All sectors employ labor, and the productivity of labor is assumed to be affected by wages. Before analyzing each of these sectors in detail, we will discuss the incentive-wage problem firms have to deal with.

### Efficiency wages and sectoral structure

A firm's wage offer influences workers' effort and thereby the efficiency of labor. We assume that the increase in efficiency resulting from the same increase in

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<sup>2</sup>Van Schaik and De Groot (1998) and Stadler (1998) derive the consumption path from an intertemporal utility-maximization problem of a representative agent who shares preferences with constant relative risk aversion (CRRA). In the presence of unemployment, however, this representative-agent problem does not follow as the result of aggregation over a finite number of employed and unemployed individuals with identical CRRA preferences. Although specified as an intertemporal optimization problem, their approach should be interpreted as based on a behavioral function. For that reason, their framework does not allow for an analysis of welfare effects, as stated in the introduction.

effort differs across sectors, although the reaction of workers' effort to changes in the wage offer is identical across sectors. This idea reflects the notion that motivation of workers, as long it does not fall below a certain minimum, plays a different role in different sectors. Eventually, it provides an explanation for the persistence of intersectoral wage differentials, a fact that has been emphasized in the empirical labor-market literature (cf. Katz and Summers 1989).

We can formalize this idea by writing sectoral labor input in efficiency units as an increasing sector-specific function of effort:

$$H_i(a + bw_i/\bar{w}) L_i, \quad H'_i > 0.$$

Consider the problem of a representative firm in sector  $i$  facing a given reference wage  $\bar{w}$ . For cost to be at a minimum at any given employment level, the firm chooses a wage rate  $w_i$  that minimizes the labor cost per unit of efficient labor. In order to simplify the notation, define the function

$$h_i(w_i/\bar{w}) \equiv H_i(a + bw_i/\bar{w}), \quad h'_i > 0.$$

The minimization problem can then be written as

$$\min_{w_i} \frac{w_i}{h_i(w_i/\bar{w})}. \quad (4)$$

The solution of this problem is well known. The efficiency wage is determined by the condition that the elasticity of the efficiency function  $h_i$  with respect to  $w_i/\bar{w}$  is equal to unity. Assuming that  $h_i$  is a strictly concave function with  $h_i(\tilde{x}_i) = 0$  for some  $\tilde{x}_i > 0$ , this condition gives a unique solution for  $w_i/\bar{w}$ . This solution can be written as  $w_i = (1 + q_i)\bar{w}$  with some constant  $q_i$ . The optimal wage is determined by a markup on the reference wage. This markup is determined solely by the characteristics of the efficiency function. Specifically, the markup is completely independent of the allocation of labor and of equilibrium dynamics. Note that although workers are assumed to be homogeneous, optimal effort is sector specific due to wage differentials. These differentials arise from the fact that efficiency resulting from a given increase in effort differs across sectors.

If we substitute for sectoral wages from the solutions  $w_i = (1 + q_i)\bar{w}$  into (1), we can derive the following restriction for the allocation of labor:

$$\sum_i (1 + q_i) L_i = L. \quad (5)$$

Additionally, we have the requirement that sectoral labor inputs cannot exceed total labor endowments:

$$\sum_i L_i \leq L. \quad (6)$$

These two equations can hold if either  $q_i = 0$  for all  $i$  or  $q_i > 0$  for at least one sector. If  $q_i < 0$  for all  $i$ , (6) cannot be fulfilled. In this case,  $\bar{w}$  would be zero and (4) has no solution. Hence, we will rule out  $q_i < 0$  for all  $i$ .

(5) shows that efficiency wages do not necessarily cause unemployment. If the wage markups are positive in some sectors and negative in others, there are allocations of labor fulfilling (5) and (6) with equality. On the other hand, if  $q_i \geq 0$  for all  $i$  and the inequality holds in a strict sense for at least one active sector, any allocation yields unemployment. In general, the rate of unemployment is determined by the sectoral structure of the economy: The greater the size of high-wage sectors relative to low-wage sectors the higher is unemployment.

### Employment decisions

In the competitive final-goods sector, the representative firm produces according to

$$Y = AL_Y^{1-\alpha} \int_0^N X_j^\alpha dj, \quad 0 < \alpha < 1, \quad (7)$$

where  $Y$  is final output,  $L_Y$  is labor employment, and  $X_j$  is the input of the  $j$ th type of specialized intermediate good ( $j = 1, \dots, N$ ). In order to preserve the notation of the full-employment version of the model in Barro and Sala-i-Martin (1995),<sup>3</sup> we use a productivity parameter  $A$  to measure labor input in efficiency units; this parameter is defined by

$$A^{1/(1-\alpha)} \equiv h_Y(1 + q_Y).$$

Obviously,  $A$  is determined endogenously in our model. However, since  $A$  is determined solely by the characteristics of the efficiency function, it can be treated as a parameter once the minimization problem determining wage markups has been solved.

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<sup>3</sup>The advantage of this proceeding is that it becomes pretty obvious that our efficiency-wage approach merely changes the constants of the full-employment model.

With the price of the final good as numeraire, the profit-maximization problem can be written as:

$$\max_{L_Y, X_j} \left\{ A L_Y^{1-\alpha} \int_0^N X_j^\alpha dj - (1 + q_Y) \bar{w} L_Y - \int_0^N P_j X_j dj \right\}. \quad (8)$$

The first-order conditions imply

$$\bar{w} = \frac{1 - \alpha}{1 + q_Y} \frac{Y}{L_Y} \quad (9)$$

$$X_j = L_Y \left( \frac{\alpha A}{P_j} \right)^{1/(1-\alpha)}. \quad (10)$$

Firms in the intermediate-goods sector produce different varieties of the intermediate good that have been developed previously and sell it to firms in the final-goods sector. Production of intermediate goods requires firms to purchase designs (blueprints) from the research sector. In order to recoup the fixed cost emanating from the purchase of designs, buying a particular design from the research sector includes the exclusive right to manufacture that design. Producers of intermediates then set their price  $P_j$  to maximize profits taking as given their demand from producers of consumer goods given by (10). To simplify the analysis, we assume that the technology used to produce intermediates is identical to the technology in the final-goods sector. This means that we suppose production of each intermediate good to cost one unit of  $Y$ , and yields the following maximization problem for the monopolist producing intermediate good of type  $j$ :

$$\max_{P_j} \left\{ [P_j - 1] X_j : X_j = L_Y \left( \frac{\alpha A}{P_j} \right)^{1/(1-\alpha)} \right\}. \quad (11)$$

The solution of this problem yields

$$P \equiv P_j = 1/\alpha, \quad \forall j \in [0, n]. \quad (12)$$

The price of intermediates is given by a constant markup on marginal cost. Since all intermediates bear the same price, producers of consumption goods employ equal quantities of each:

$$X \equiv X_j = L_Y (\alpha^2 A)^{1/(1-\alpha)}. \quad (13)$$

Hence, all producers of intermediates make profits of  $(1 - \alpha)X/\alpha$ . The present value of these profits is given by

$$V(t) = \frac{1 - \alpha}{\alpha} (\alpha^2 A)^{1/(1-\alpha)} \int_t^\infty L_Y(\tau) e^{-\int_t^\tau r(s) ds} d\tau. \quad (14)$$

Due to patent protection, these profits cannot be competed away by entering firms imitating previously developed intermediate goods.<sup>4</sup> Potential entrants, however, may buy newly developed designs from the R&D-sector. Competition among potential entrants ensures that the price of a newly developed design will be equal to the present value of profits to be earned by an intermediate-good producer.

Firms may enter freely into R&D. We assume that the production function for product innovation is given by

$$\dot{N} = NL_R/\eta, \quad (15)$$

implying that the R&D cost in units of final output is  $(1 + q_R)\bar{w}\eta/N$ . Here, labor productivity is measured by the parameter  $\eta$ , which is defined by

$$\eta^{-1} \equiv h_R(1 + q_R).$$

### 2.3 Equilibrium

We concentrate on equilibria with positive growth. In these cases, the free-entry condition implies that  $V(t) = (1 + q_R)\bar{w}(t)\eta/N(t)$  holds for all  $t$ . The level of final-goods' output is determined from eqs. (7) and (13) as

$$Y = L_Y N (\alpha^{2\alpha} A)^{1/(1-\alpha)}. \quad (16)$$

Solving for  $\bar{w}$  by substituting for  $Y$  in (9) gives

$$\bar{w} = \frac{1 - \alpha}{1 + q_Y} N (\alpha^{2\alpha} A)^{1/(1-\alpha)}. \quad (17)$$

Given our sectoral structure, the labor-market restriction (5) reads

$$(1 + q_Y)L_Y + (1 + q_R)L_R = L. \quad (18)$$

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<sup>4</sup>An alternative way to justify that differentiated goods are not imitated is to assume positive imitation cost (Cf. Grossman and Helpman 1991: 49).

Substituting for  $\bar{w}$  from (17) and for  $L_Y$  from (18) in the arbitrage condition gives

$$\frac{\eta}{\alpha} = \int_t^\infty \left[ \frac{L}{1+q_R} - L_R(\tau) \right] e^{-\int_t^s r(s) ds} d\tau. \quad (19)$$

With the interest rate determined by the consumption sector as  $r(t) = \rho$ , the arbitrage condition can hold for all  $t$  only if the integral is constant. This requires a constant labor allocation and implies that the model has no transitional dynamics. We can then solve for the growth rate from (19):

$$g(L, \rho) \equiv \frac{L_R}{\eta} = \frac{L}{(1+q_R)\eta} - \frac{\rho}{\alpha}, \quad (20)$$

where  $\partial g(\cdot)/\partial L > 0$  and  $\partial g(\cdot)/\partial \rho < 0$ . Obviously, the growth rate in (20) differs from the growth rate derived from the full-employment version only by the fact that the exogenously given labor supply  $L$  is multiplied by the constant  $1/(1+q_Y)$  (cf. Barro and Sala-i-Martin 1995: 229).

We can now analyze the correlation between the growth rate and the rate of unemployment. Substituting for  $L_R$  in the labor-market restriction (18) yields employment in the final-goods sector as

$$L_Y = \frac{1+q_R}{1+q_Y} \frac{\rho\eta}{\alpha}. \quad (21)$$

The unemployment rate  $\mu \equiv 1 - (L_R + L_Y)/L$  can then be calculated as

$$\mu(L, \rho) = \frac{1}{1+q_R} + \frac{\rho}{L} \frac{\eta}{\alpha} \left( 1 - \frac{1+q_R}{1+q_Y} \right). \quad (22)$$

The signs of the partial derivatives of  $\mu$  depend on the intersectoral wage differential. The growth rate is the higher, the more labor is employed in the R&D-sector. On the other hand, the rate of unemployment is the higher, the more labor is employed in the high-wage sector. Hence, growth and unemployment will be positively correlated if the R&D-sector is the high-wage sector, and they will be negatively correlated otherwise.

A decisive feature of our model is that both growth and unemployment are determined by the relative labor employment of the R&D sector, i.e. by the *intersectoral allocation* of labor. The intersectoral allocation of labor does not change along a balanced growth path. Higher growth, however, also brings about higher reallocation of labor within the intermediate-goods sector, as newly invented intermediates are produced. In the present model, this *intrasectoral reallocation*

has no impact on the unemployment rate. This stands in sharp contrast to the results derived from models based on the matching approach. In this class of models (cf. Aghion and Howitt 1994) it is the *reallocation of labor within* the sector producing intermediates that determines the unemployment rate. Matching unemployment generated by intrasectoral labor reallocation can be thought of as complementary to the efficiency-wage unemployment discussed in the present paper. However, one must be careful in evaluating this re-allocative aspect of growth. Along a balanced growth path, permanent labor reallocation within the intermediate-goods sector path is an inevitable side effect of growth driven by an expansion of the number of intermediate goods. Firms producing newly developed intermediates continually draw labor from producers of previously developed intermediates. In growth models based on improving the qualities of a given number of intermediates (as in Aghion and Howitt), these reallocation effects occur only if quality improvements involve a permanent change in leadership positions within the intermediate-goods sector (leapfrogging by “creative destruction”). But growth will generate no intrasectoral labor reallocation at all if quality improvements are realized by industry leaders. The latter occurs, if leaders have a cost advantage in research activities. Together with the fact that there is hardly empirical evidence for continual leapfrogging, this casts doubt upon the importance of the re-allocative aspect of growth which drives the results in the model of Aghion and Howitt.

### 3 Wage subsidies and welfare

Several authors have suggested that the government should subsidize employment in order to reduce unemployment (cf., e.g., Phelps 1994). On the other hand, the literature on growth theory proposes subsidization of R&D activities (in order to internalize the research spillovers) and of the purchase of intermediate goods (in order to neutralize the effect of monopolistic pricing). Given our analysis so far, one would conjecture that unemployment can be reduced by subsidizing employment in the low-wage sector. Additionally, we would expect that such a policy should raise economic growth if employment is subsidized in the R&D sector. Promoting the purchase of intermediates, however, should reduce growth and raise (lower) unemployment if the R&D-sector is the low-wage (high-wage)

sector.

We model subsidization as subsidies whereby the government pays (i) a fraction  $\phi_i$  of wage payments in sector  $i = Y, R$  and (ii) a fraction  $\phi_X$  of the purchase cost of intermediate goods. All subsidies are assumed to be financed by lump-sum taxation. First, note that wage subsidies have no effect on workers' incentives. Hence, they do not alter the wage markups  $q_i$ . Nevertheless, wage subsidies have an impact on labor cost of firms and alter the equilibrium conditions of the model. Labor demand in the final-goods sector is given by

$$(1 - \phi_Y)\bar{w} = \frac{1 - \alpha}{1 + q_Y} \frac{Y}{L_Y}, \quad (23)$$

and the R&D cost is  $(1 - \phi_R)(1 + q_R)\bar{w}\eta/N$ . Subsidization of the purchase of intermediate goods alters the demand by the final-goods sector to

$$X = L_Y \left( \frac{\alpha^2 A}{1 - \phi_X} \right)^{1/(1-\alpha)}. \quad (24)$$

Taking account of these modifications in the arbitrage condition yields the growth rate

$$g(L, \rho, \phi_R, \phi_Y, \phi_X) \equiv \frac{L_R}{\eta} = \frac{L}{(1 + q_R)\eta} - \frac{\rho}{\alpha} \frac{1 - \phi_R}{1 - \phi_Y} (1 - \phi_X)^{\alpha/(\alpha-1)}, \quad (25)$$

where  $\partial g/\partial \phi_R > 0$ ,  $\partial g/\partial \phi_Y < 0$ , and  $\partial g/\partial \phi_X < 0$ . Obviously, wage subsidies affect growth only if they are differentiated, but they have no effect if they are identical for all firms. The intuition for this result is that subsidizing employment in all sectors by equal rates affects profitability of all firms in the same way. In the end, this policy promotes neither sector leaving the allocation of labor unchanged. Since both the growth rate and the unemployment rate depend on labor employment in the R&D sector, homogeneous wage subsidies have no effect on growth and unemployment at all. On the other hand, subsidizing only the R&D sector promotes growth. This policy will also reduce the unemployment rate if the R&D sector is the low-wage sector, but raise it otherwise. Finally, subsidizing the purchase of intermediates raises the production of both final goods and intermediates, and draws labor from the R&D-sector thus reducing growth.

Our analysis so far abstracted from welfare properties of policies designed for increasing economic growth or/and reducing unemployment. From the analysis of the full-employment version of the model by Barro and Sala-i-Martin (1995)



we know, that promoting growth by appropriately subsidizing R&D and the purchase of intermediates is welfare improving.<sup>5</sup> As we will show in the following, their argument does not generalize to the case of unemployment. This result may not be striking once we account for aggregate employment to affect welfare. Surprisingly, however, there exist parameter constellations where taxing wages in the R&D sector while at the same time subsidizing the purchase of intermediate goods improves welfare despite reducing growth *and* employment. This result can hold although individuals derive disutility from being unemployed.

By selecting subsidy rates, the government decides upon the allocation of labor and the production of intermediates. This allows us to solve for the optimal subsidy scheme by choosing the welfare-maximizing allocation of labor and output of the intermediate-goods sector. With  $AL_Y^{1-\alpha}NX^\alpha - NX$  and omitting constant terms from the maximand, the problem of the government can be written as

$$\max_{L_j, X} \int_t^\infty \left[ AL_Y^{1-\alpha}NX^\alpha - NX - (a-z)(L_R + L_Y) - zL \right] e^{-\rho(\tau-t)} d\tau \quad (26)$$

$$s.t.: \dot{N} = L_R N / \eta$$

$$L = (1 + q_R)L_R + (1 - q_Y)L_Y.$$

The structure of this problem allows for solving it by a two-step maximization procedure. First we determine the optimal  $X$  as a function of  $L_Y$  from the static problem

$$\max_X AL_Y^{1-\alpha}NX^\alpha - NX. \quad (27)$$

This determines production of intermediates as

$$X = (\alpha A)^{1/(1-\alpha)} L_Y. \quad (28)$$

Contrary to the decentralized solution, the social planner allocates more resources to the production of intermediates for any given employment in the final-goods sector. The decentralized solution for  $X$  in (13) is  $\alpha^{1/(1-\alpha)} < 1$  times the solution

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<sup>5</sup>Note that this result does not hold for growth models based on expanding the number of product varieties in general. Benassy (1998) shows that the model's welfare implications crucially depend on the specification of the final-goods sector's technology. Given a more general form of that sector's production function, growth can also be too high in a decentralized economy. The latter result has frequently been viewed as a feature solely of growth models based on expanding the qualities of a given set of product varieties.

given by (28). This is exactly the same result as in the full-employment version of the model (cf. Barro and Sala-i-Martin 1995: 229). The optimal policy is to subsidize intermediates at the rate  $\phi_X = 1 - \alpha$  ensuring that the demand for intermediates under subsidization (given by (24)) corresponds to demand given by (28).

We can then determine the allocation of labor. Since the model has no transitional dynamics, labor allocation must be constant over time. This allows us to solve for  $N$  from the dynamic constraint:

$$N(\tau) = N(t)e^{(L_R/\eta)\tau}. \quad (29)$$

With (28) and (29), the maximization problem (26) reduces to

$$\max_{L_R} \left\{ B \int_t^\infty [L - (1 + q_R)L_R] e^{(L_R/\eta - \rho)(\tau - t)} d\tau - (a - z) \int_t^\infty \left[ L_R \left( 1 - \frac{1 + q_R}{1 + q_Y} \right) - \frac{L}{1 + q_Y} \right] e^{-\rho(\tau - t)} d\tau \right\}, \quad (30)$$

where  $B$  is some positive constant given by  $B \equiv (1 - \alpha)(\alpha^\alpha A)^{1/(1 - \alpha)} N(t)/(1 + q_Y)$ . Obviously, for a sufficiently small value of  $\rho$  ( $\rho < L/[\eta(1 + q_R)]$ ) the first integral in (30) will not converge. In this case, utility will be maximized by allocating labor completely to the R&D sector by choosing subsidy rates such that  $(1 - \phi_R)/(1 - \phi_Y) = 0$  (cf. eq. (25)). By accumulating  $N$  at the maximum possible rate, consumption becomes infinite as  $\tau$  goes to infinity. Due to the linearity of the instantaneous utility function, this path maximizes utility although there is zero consumption in finite time.

On the other hand, both integrals converge and welfare will be maximized for  $0 \leq L_R < L/(1 + q_R)$  if  $\rho \geq L/[\eta(1 + q_R)]$ . In this case, the values of the parameters  $a$  and  $z$  crucially affect the optimal allocation of labor. Since there are no theoretical restrictions on the magnitude of these parameters,  $L_R$  can take on any admissible value. The latter is true irrespective of the sign of the wage differential, i.e. irrespective of the sign of the correlation between growth and unemployment. The case that growth and employment in the decentralized economy exceed the optimal rates of growth and employment is certainly within the range of possibilities. The optimal policy then calls for a “taxation” of employment in the R&D sector (i.e.  $(1 - \phi_R)/(1 - \phi_Y) > 1$ ) thus reducing growth and aggregate employment.

The economic intuition behind this result is the following. In addition to the beneficial effect of augmenting growth by internalizing intertemporal spillover effects from innovation, subsidizing R&D affects welfare by its impact on aggregate employment. Higher employment lowers the disutility of unemployment, while at the same time raising the disutility of effort. In general, the net effect is ambiguous. Moreover, since the welfare effect from the change in aggregate employment can be made arbitrarily strong, it may well dominate the benefit from increasing growth. Hence, a policy that raises growth and reduces unemployment at the same time (promotion of the R&D sector when this sector has the lower wages) may well reduce welfare if its effect on the disutility of effort is sufficiently strong.

We can now use the sign of the wage differential to predict effects of a growth policy aimed at reducing unemployment and raising welfare. Such a policy cannot simultaneously raise growth, aggregate employment, and aggregate welfare if the R&D sector is the high-wage sector. Our model predicts that promoting growth reduces aggregate employment in this case. Aggregate welfare rises only if the disutility from unemployment is sufficiently small relative to the disutility of effort. On the other hand, if the R&D sector is the low-wage sector, promotion of growth raises aggregate employment; the beneficial effect on aggregate welfare, however, only occurs if the disutility of unemployment is sufficiently high relative to the disutility of effort. The popular view of promoting growth in order to reduce unemployment *and* to raise welfare is only confirmed by our model in this special case.

## 4 Conclusions

By integrating a simple efficiency-wage theory into an otherwise standard model of endogenous growth we simultaneously endogenize an economy's growth rate and unemployment rate. Our theoretical analysis has shown that the sign of the correlation between the rate of growth and the rate of unemployment is ambiguous in general, but related to the sign of intersectoral wage differentials. We have shown that the correlation between growth and unemployment is positive if the research sector is the high-wage sector of the economy, and negative, if the research sector is the low-wage sector.

Due to the simplicity of our approach, many decisive properties of the full-

employment version of the model are preserved, at least as far as its positive results are concerned. Welfare results, however, may change considerably once one allows for employment (via disutility of effort and disutility of being unemployed) to affect utility. An economy may even be worse off in an equilibrium with higher growth *and* lower unemployment, if disutilities of effort are sufficiently strong. The intuition behind this result is simply that individuals have to work so hard for higher growth that the welfare loss from the increase in effort dominates the welfare gains from internalizing research-spillover effects on the one hand and from lower unemployment on the other hand. This rather counterintuitive welfare effect cannot be excluded although we account for the fact that the state of being unemployed has a negative effect on individual utilities.

The model can be expanded or generalized in several ways. First, we can generalize our model and allow for different technologies and different efficiency functions in the final-goods sector and the intermediate-goods sector. In such an expanded version of the model, the R&D sector, which typically employs only a very small share of an economy's labor force, does not have all the burden for explaining the relation between the growth rate and the rate of unemployment. However, the technical analysis becomes quite intricate without generating really new insights. Secondly, we can integrate the efficiency-wage mechanism into other models of R&D-driven growth. The reasons for having chosen the Romer framework were the simplicity of the technical analysis and the fact that this model is so well known. It is also well known that the Romer model, among others, has been criticized on its implication that larger countries should have larger growth rates (cf. Jones 1995). For the present analysis, this scale effect implies some correlation of country size and its rate of unemployment, a correlation which is unlikely to show up in the data. The mechanism driving the relation of the rate of growth and the unemployment rate, however, is independent of the special growth model we use. *Any* model where the growth rate is correlated to the relative size of the R&D sector gives us the same results with respect to the growth-unemployment nexus (cf. Jones, 1999, for an overview of this class of models). Another promising extension is the simultaneous analysis of efficiency-wage unemployment and matching frictions within the present framework thus allowing both the intersectoral allocation and intrasectoral reallocation of labor to affect unemployment. Eventually, substituting for the representative-agent

framework by an overlapping generation approach as it is used, e.g., in Bean and Pissarides (1993) would allow for an analysis of unemployment-induced distributional effects on the growth rate.

## References

- Aghion, P., and Howitt, P. (1994) "Growth and unemployment," *Review of Economic Studies* 61, 477-494.
- Akerlof, G.A. (1982) "Labor contracts as a partial gift exchange," *Quarterly Journal of Economics* 97, 543-569.
- Albert, M., and Meckl, J. (1998) "A dual general equilibrium approach to pure efficiency-wage unemployment," mimeo.
- Albert, M., and Meckl, J. (1999) "Wage differentials, factor intensities, and unemployment: a Heckscher-Ohlin trade model," mimeo.
- Bean, C., and Pissarides, C. (1993) "Unemployment, Consumption and Growth," *European Economic Review* 37, 837-854.
- Benassy, J.-P. (1998) "Is there always too little research in endogenous growth with expanding product variety?" *European Economic Review* 42, 61-69.
- Caballero, R.J. (1993) "Comments: Unemployment, consumption and growth, by Charles Bean and Chris Pissarides" *European Economic Review* 37, 855-859.
- Grossman, G.M., and Helpman, E. (1991) *Innovation and growth in the global economy*, MIT Press: Cambridge/Mass.
- Jones, C.I. (1995) "R&D-based models of economic growth," *Journal of Political Economy* 103, 759-784.
- Jones, C.I. (1999) "Growth: with or without scale effects," *American Economic Review (Papers & Proceedings)* 89, 139-144.
- Katz, L.F., and Summers, L.H. (1989) "Can interindustry wage differentials justify strategic trade policy?," in: Feenstra, R.C. (ed.), *Trade policies for international competitiveness*, NBER Conference Report, The University of Chicago Press: Chicago, 85-116.
- Krueger, A.B., and Summers, L.H. (1988) "Efficiency wages and the inter-industry wage structure," *Econometrica* 56, 259-293.
- Oswald, A.J. (1997) "Happiness and Economic Performance," *Economic Journal* 107, 1815-1831.

- Phelps, E.S. (1994) *Structural slumps: the modern equilibrium theory of unemployment, interest, and assets*, Harvard University Press: Cambridge/Mass.
- Ramser, H.J. (1997) "Beschäftigung und Wirtschaftswachstum," *Ifo-Studien* 43, 347-365.
- Romer, P.M. (1990) "Endogenous technological change," *Journal of Political Economics* 98, S71-S102.
- Solow, R.M. (1979) "Another possible source of wage stickiness," *Journal of Macroeconomics* 1, 79-82.
- Stadler, M. (1998) "Innovation, endogenous growth, and unemployment," mimeo.
- Summers, L.H. (1989) "Relative wages, efficiency wages, and keynesian unemployment," *American Economic Review (Papers and Proceedings)* 78(2), 383-388.
- Van Schaik, B.T.M., and De Groot, H.L.F. (1998) "Unemployment and endogenous growth," *Labour* 12(2), 189-219.
- Winkelmann, L. and Winkelmann, R. (1998) "Why are the unemployed so unhappy? Evidence from panel data," *Economica* 65, 1-15.