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# Equilibrium Unemployment and Capital Intensity Under Product and Labor Market Imperfections\*

## Abstract

We study the implications of product and labor market imperfections for equilibrium unemployment under both exogenous and endogenous capital intensity. With endogenous capital intensity, stronger labor market imperfections always increase equilibrium unemployment. The relationship between the long-run unemployment and the intensity of product market competition is not necessarily monotonic, but there is an elasticity of substitution below one such that the long-run equilibrium unemployment is an increasing function of the product market imperfections when the elasticity exceeds this threshold. Higher interest rates increase (decrease) the long-run equilibrium unemployment when the elasticity of substitution is below (above) one.

**JEL Classification:** E22, E24, J51, L11.

**Keywords:** equilibrium unemployment, product market imperfections, capital intensity, wage bargaining.

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## I. Introduction

The employment consequences of long-term investments have for a long time been a controversial issue in economics and this issue seems to underlie many disputes between firm owners and labor unions. In conventional models of imperfectly competitive labor markets, for example Layard, Nickell and Jackmann (1991), the investments have no effect on equilibrium unemployment. This is due to the specification of a Cobb-Douglas production function, which implies a constant wage elasticity of labor demand. For this class of production functions, investments or interest rates will have no effect on the wage determination, achieved through wage negotiations due to the constant wage elasticity, and therefore no effect on equilibrium unemployment.

Many reservations can be raised against the Cobb-Douglas specification, according to which the elasticity of substitution between labor and capital is equal to one. For the U.S. economy empirical studies have produced estimates according to which the elasticity of substitution empirical studies lies well below one (see e.g. Lucas (1969), Chirinko (2002), Chirinko et.al (2004) and Antras (2004)). Also empirical evidence concerning international data seems to consistently yield estimates, which do not lie in conformity with the Cobb-Douglas specification (see e.g. Rowthorn (1995), (1999), Duffy and Papageorgiou (2000) and Pessoa et. al (2004)). Berthold et. al (1999) have argued that the elasticity of substitution between capital and labor for Germany and France are higher than one. It has also been argued that when trying to explain variations in the labor share there is a need to depart from the usual assumption of a Cobb-Douglas production function (see Bentolila and Saint-Paul (2002)). Moreover, and related, medium- to long-term changes in unemployment tend to be correlated with medium- to long-term changes in interest rates and thereby private investment – a feature which seems to be inconsistent with predictions generated by models with Cobb-Douglas production functions (for some empirics, see e.g. Herbertsson and Zoega (2002)). On the theoretical side Phelps (2004) has argued, applying an intertemporal consumer market model, that higher real interest rates will raise the mark-ups in the product markets, leading to higher equilibrium unemployment. In the present paper we abandon the Cobb-Douglas specification and introduce a link between the long-

term investment decisions and the negotiated wages by focusing on a more general class of CES production functions.

We analyze the effects of simultaneous labor and product market imperfections on equilibrium unemployment under exogenous as well as endogenous capital intensity. Our study fulfils several purposes. Firstly, we explore the impact of long-term investments on wage formation, and thereby on unemployment, in an economy characterized by labor and product market imperfections. Secondly, we investigate the consequences of imperfections in the product market on equilibrium unemployment. We design a theoretical model, which establishes important interaction effects between labor market imperfections, product market imperfections and long-term investments. We demonstrate how these effects have implications for equilibrium unemployment under exogenous capital intensity. Finally, we characterize the qualitative properties of equilibrium unemployment in the long run under endogenous capital intensity with a particular focus on the total long-run effects of interest rates and of labor and product market imperfections on equilibrium unemployment.

Some employment consequences of intensified competition and deregulation in product markets have been analyzed in the recent literature. However, in this literature the potential role of investments has been abstracted away by postulating a production function with labor as the only production factor either in a linear (see Blanchard and Giavazzi (2003), Ebell and Haefke (2003)) or Cobb-Douglas form (see Spector (2004)). Blanchard (1997) has developed a model of employment and capital accumulation, when firms are assumed to be monopolistically competitive in the product market. He assumes that each firm uses one unit of capital, which it combines with a variable amount of labor to produce output. Hence at the firm level the capital stock is not modeled and at the aggregate level it is simply equal to the number of firms through entry and exit decisions in the long run. Caballero and Hammour (1998) study the effects of match-specific, i.e. “appropriable”, investments and labor market institutions on both capital accumulation and unemployment, but they do not model product market imperfections.

In what follows we extend the approach applied in these models by focusing on a general class of CES production functions within a framework where we

capture the product market imperfections through monopolistic competition and the labor markets imperfections through a ‘right-to-manage’ union bargaining model. In particular, we incorporate the general CES-type production function with capital and labor inputs in such a way that the elasticity of substitution between the production factors will depend on the capital-labor ratio.<sup>1</sup>

In the present analysis we initially show that intensified product market competition will decrease equilibrium unemployment under exogenous capital intensity. The effect of capital intensity on equilibrium unemployment turns out to depend on the specification of the production function. Higher capital intensity will moderate the negotiated wage rate and thereby reduce equilibrium unemployment when the elasticity of substitution between capital and labor is less than one. However, higher capital intensity will have reverse effects when the elasticity of substitution is higher than one but smaller than the price elasticity of demand in the product market. In particular, the relationship between the capital stock and equilibrium unemployment would vanish in the special case of the Cobb-Douglas production function. Further, we determine the capital intensity consistent with a long-run equilibrium in the capital market. We find that the long-run equilibrium unemployment under endogenous capital intensity is an increasing (decreasing) function of the interest rate when the elasticity of substitution between capital and labor is lower (higher) than one. Finally, we characterize the qualitative properties of equilibrium unemployment in the long run with a particular focus on the total effects of labor and product market imperfections. These total long-run effects of labor and product market imperfections on equilibrium unemployment incorporate both direct effects and indirect mechanisms through the effects on wage formation and long-run capital investments. We find that the long-run equilibrium unemployment under endogenous capital intensity is always an increasing function of the relative bargaining power of the labor unions, whereas there is, in general, not a monotonic relationship between the long-run unemployment and the intensity of product market competition. However, in this respect we find that there is critical threshold below one of the elasticity of substitution between capital and labor such that the long-run equilibrium unemployment is a decreasing function of the

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<sup>1</sup> Hoon (1998) has developed a model with a different focus to study the interactions of unemployment and economic growth by assuming that the elasticity of substitution between capital and labour is less than one under the efficiency wage hypothesis.

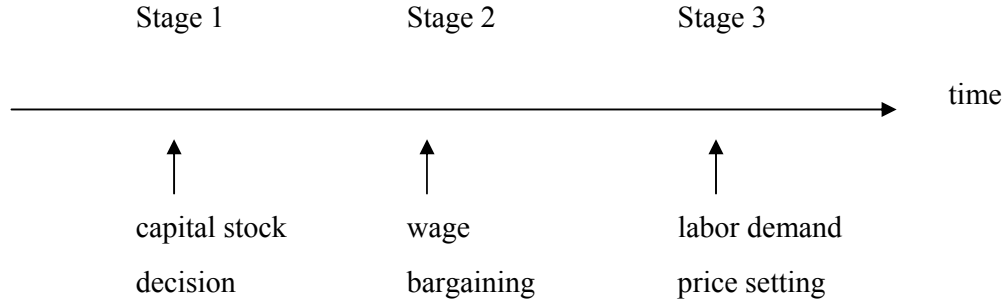
intensity of product market competition when the elasticity exceeds this threshold. Our new theoretical findings suggest important topics for future empirical research.

We proceed as follows. Section II presents the basic structure of the model as well as the time sequence of decisions. Price setting and labor demand by firms are studied in section III. In section IV we analyze the wage determination through Nash bargaining subject to price setting and labor demand, while taking the capital intensity as given. Section V explores the determinants of equilibrium unemployment under exogenous capital intensity. In section VI we investigate the long-run investment decisions under labor and product market imperfections and characterize the determinants of the long-run equilibrium unemployment when capital intensity is endogenous. Finally, in section VII we present concluding comments.

## **II. Basic Framework**

We focus on a model with product and labor market imperfections. In the long run, at stage 1, firms commit themselves to their investment programs, which determine the capital stocks. The investment decisions are made in anticipation of their effects on wage setting, price setting and labor demand. At stage 2 there is wage negotiation between firms and labor unions and at this stage the firms are committed to their investments. The wage negotiations take place in anticipation of the consequences for labor demand and price setting. Finally, at stage 3 firms make employment decisions and set prices by taking the negotiated wage rate and investment decision as given.

We summarize the time sequence of decisions in Figure 1. In the subsequent sections we derive the decisions taking place at different stages by using backward induction.



**Figure 1: Time sequence of decisions**

This timing structure captures the idea of long-term investment decisions, which are inflexible at the stage when the wage negotiations are undertaken. Such a timing structure seems plausible when the investments represent, for example, irreversible technology choices. Of course, the relative timing between the negotiated wage setting and the investment decisions could also be reversed so as to capture that the negotiated outcome is a long-term contract relative to the investment decision (see e.g. Anderson and Devereux (1991) or Cahuc and Zylberberg (2004), chapter 9). In a recent study Hellwig (2004) has extensively compared a number of key properties associated with these two alternative timing structures within the framework of a general equilibrium model. He suggests that although the long-term labor demand – with endogenous investment – is more elastic than the short-term demand, it does not necessarily lead to a less aggressive wage policy if the reactions of “temporary-equilibrium prices”, in particular the reactions of real interests, anticipate the wage policies.

We postulate (for each firm  $i$ ) a CES production function with constant returns to scale according to

$$R_i(K_i, L_i) = \left[ (1-a)K_i^{\frac{\sigma-1}{\sigma}} + aL_i^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}, \quad i = 1, \dots, n \quad (1a)$$

where  $K_i$  denotes firm  $i$ 's capital stock,  $L_i$  is the amount of labor, and  $a$  and  $\sigma$  are parameters satisfying  $0 < a < 1$  and  $\sigma > 0$ , respectively. The parameter  $a$  is often called the distribution parameter (see e.g. Arrow et al (1961)), while  $\sigma$  captures the elasticity of substitution between capital and labor. This production function lies in conformity with empirics and opens up a rich and interesting relationship between the capital stock and equilibrium unemployment in the short or medium run as well

as in the long run, i.e. no matter whether the capital stock is exogenous or endogenous. For reasons of comparison we also repeatedly consider the conventional case of Cobb-Douglas production function

$$R_i(K_i, L_i) = K_i^{1-a} L_i^a, \quad i = 1, \dots, n \quad (1b)$$

where the elasticity of substitution between capital and labor is equal to one. Notice that in (1b) the parameter  $a$  defines the labor share of production.

### III. Price Setting and Labor Demand

The product market is modeled to operate with monopolistic competition a la Dixit and Stiglitz (1977) and the firms face consumers endowed with the CES-utility function

$$U = \left[ n^{-\frac{1}{s}} \sum_{i=1}^n D_i^{\frac{s-1}{s}} \right]^{\frac{s}{s-1}}, \quad (2)$$

where  $s$  denotes the elasticity of substitution between products and where  $n$  is the number of products (and firms). We take this elasticity of substitution as the measure of the degree of product market competition.<sup>2</sup> A higher elasticity of substitution means a higher degree of product market competition. In particular, the limiting case of perfect competition is associated with the elasticity of substitution  $s$  approaching infinity.

A firm  $i$  decides on price and employment so as to maximize the following profit function

$$\max_{p_i, L_i} \pi_i = p_i R_i(K_i, L_i) - w_i L_i \quad (3)$$

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<sup>2</sup> Blanchard and Giavazzi (2003) have analyzed the case where in the long-run there is free entry of firms so that  $s$  is endogenous in that respect. The utility function (2) has the special feature that an increase in the number of products does not increase utility directly (for more discussion in this respect, see Blanchard and Giavazzi (2003), p. 882). In our framework the number of firms is assumed to be fixed, but, in contrast to Blanchard and Giavazzi, capital intensity is endogenously determined in the long-run.



At this stage the firm takes the negotiated wage rate  $w_i$  and the capital stock  $K_i$  as given. From the underlying utility function, given by (2), the demand in the product market can be seen to be of the form

$$D_i = \frac{M}{P} \left( \frac{p_i}{P} \right)^{-s}, \quad (4)$$

where  $p_i$  is the price of good  $i$ ,  $P \equiv \left[ \frac{1}{n} \sum_{i=1}^n p_i^{1-s} \right]^{\frac{1}{1-s}}$  is the index of the aggregate price level,  $M$  is the aggregate nominal income and  $s > 1$  is the elasticity of substitution between different products.<sup>3</sup> Thus,  $M/P$  denotes the real income. Furthermore, if we assume that the rents from capital are competed away in the long run, the aggregate nominal income is

$$M = N [(1-u)w + uB], \quad (5)$$

where  $N$  denotes the number of workers, all unionized, in the economy,  $u$  is the unemployment rate,  $w$  is the negotiated wage rate and  $B$  is the unemployment compensation. It is important to point out that at this stage of the game the aggregate nominal income  $M$  is exogenous, but later on both the wage rate  $w$  and the unemployment rate  $u$  are endogenized.

We can rewrite the CES production function (1a) as

$$L_i = \left[ \frac{1}{a} R_i^{\frac{\sigma-1}{\sigma}} - \frac{1-a}{a} K_i^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}. \quad (6)$$

By imposing market-clearing in the product markets,  $D_i = R_i$ , and by using (6) we can re-express the profit function (3) for the purpose of price setting according to

$$\underbrace{\max}_{p_i} \pi_i = p_i D_i - w_i L_i = M \left( \frac{p_i}{P} \right)^{1-s} - w_i \left( \frac{1}{a} \left[ \frac{M}{P} \left( \frac{p_i}{P} \right)^{-s} \right]^{\frac{\sigma-1}{\sigma}} - \frac{1-a}{a} K_i^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \quad (7)$$

where  $M$ ,  $P$ ,  $K_i$  and  $w_i$  are taken as given.

The necessary first-order condition associated with (7) can be expressed as

$$(1-s) + w_i \left( \frac{1}{a} \left[ \frac{M}{P} \left( \frac{p_i}{P} \right)^{-s} \right]^{\frac{\sigma-1}{\sigma}} - \frac{1-a}{a} K_i^{\frac{\sigma-1}{\sigma}} \right)^{\frac{1}{\sigma-1}} \frac{1}{a} \frac{s}{p_i} = 0 \quad (8)$$

We can reformulate (8) according to the equation

$$\left( \frac{(s-1)a}{sw_i} \right)^{\sigma-1} p_i^{\sigma-1} = \frac{1}{a} \left( \frac{M}{P} \left( \frac{p_i}{P} \right)^{-s} \right)^{\frac{\sigma-1}{\sigma}} - \frac{1-a}{a} K_i^{\frac{\sigma-1}{\sigma}} \quad (9)$$

By imposing the symmetry condition  $p_i = P$  for all  $i$  (9) can be simplified according to the following price-setting rule

$$p_i|_{\sigma \neq 1} = \left( \left( M^{\frac{\sigma-1}{\sigma}} - (1-a)K_i^{\frac{\sigma-1}{\sigma}} \right)^{\frac{1}{\sigma-1}} w_i \mu(s) a^{\frac{\sigma}{\sigma-1}} \right)^{\frac{\sigma}{\sigma+1}} \quad \text{for all } i, \quad (10a)$$

where the mark-up factor,  $\mu(s) = s/(s-1)$ , associated with the pricing equilibrium, depends negatively on the elasticity of substitution between products.

From (10a) and using the definition of the aggregate nominal income,  $M$  in (5), we can attach the following qualitative properties to the price setting:

$$\frac{\partial p_i}{\partial w_i} > 0, \quad \frac{\partial p_i}{\partial B} > 0, \quad \frac{\partial p_i}{\partial \mu} > 0, \quad \frac{\partial p_i}{\partial u} < 0, \quad \frac{\partial p_i}{\partial K_i} < 0 \quad (11)$$

In the case of the Cobb-Douglas production function (1b) we can use a similar procedure to find the following price setting rule

$$p_i|_{\sigma=1} = a^{-a} \left( \frac{M_i}{K_i} \right)^{1-a} (w_i \mu(s))^a \quad \text{for all } i \quad (10b)$$

As one can see, the qualitative properties of (10b) are similar to those of (10a).

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<sup>3</sup> A formal standard proof is available upon request.

We can now summarize our characterization of the optimal price setting by firms in

**Proposition 1** *Higher wage rates, higher unemployment compensations or lower elasticities of substitution between products will raise the equilibrium price in the product market, whereas higher unemployment rates or higher capital stocks will decrease it, ceteris paribus.*

The pass-through effects - characterized in Proposition 1 - seem to appeal to intuition and several of these features are well known from the literature. An important new aspect in Proposition 1 is the role of the capital stock for the price setting. An increase in the capital stock will increase production and thereby induce lower prices.<sup>4</sup> This feature has not been captured in the earlier wage bargaining literature under imperfectly competitive product markets (see Blanchard and Giavazzi (2003), Ebell and Haefke (2003) and Spector (2004)).

In order to simplify notation we from now on mostly abstract from the firm-specific index associated with product  $i$ . Doing so the necessary first-order condition determining labor demand can be written as

$$\pi_L = pR_L - w = 0 \quad (12)$$

with the associated second-order condition  $\pi_{LL} = pR_{LL} + p_L R_L < 0$ . Using the CES production function (1a) the first-order condition (12) can be expressed as

$$\left[ (1-a)K^{\frac{\sigma-1}{\sigma}} + aL^{\frac{\sigma-1}{\sigma}} \right]^{\frac{1}{\sigma-1}} aL^{-\frac{1}{\sigma}} = \frac{w}{p} \text{ so that the labor demand is}$$

$$L|_{\sigma \neq 1} = K \left[ \frac{1}{1-a} \left( \frac{w}{ap} \right)^{\sigma-1} - \frac{a}{1-a} \right]^{\frac{\sigma}{1-\sigma}} \quad (13a)$$

with  $L_K > 0$  and  $L_{(w/p)} < 0$ . In the case of the Cobb-Douglas production function (1b) we end up with the labor demand

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<sup>4</sup> This provides an alternative argument for the result by Phelps (1994), according to which lower interest rates will decrease the pricing mark-ups.

$$L|_{\sigma=1} = K \left( \frac{w}{ap} \right)^{\frac{1}{1-a}} \quad (13b)$$

with  $L_K > 0$  and  $L_{(w/p)} < 0$  as well. In the labor demand functions (13a) and (13b) the product price is endogenous as it depends on the wage rate.

The wage elasticity of labor demand, which turns out to be important later on, can be written in the case of the CES production function (1a) as (see Appendix A)

$$\eta(k,s)|_{\sigma \neq 1} = -\frac{L_w w}{L} = \frac{\sigma \left( 1 + \frac{1-a}{a} k^{\frac{\sigma-1}{\sigma}} \right)}{\frac{\sigma}{s} + \frac{1-a}{a} k^{\frac{\sigma-1}{\sigma}}} \quad (14a)$$

while the Cobb-Douglas production function leads to

$$\eta(s)|_{\sigma=1} = -\frac{L_w w}{L} = \frac{1}{1-a((s-1)/s)}, \quad (14b)$$

where  $(s-1)/s = \mu(s)^{-1}$ . From (14a) we can conclude that the wage elasticity of labor demand depends on the following four factors: the elasticity of substitution between capital and labor ( $\sigma$ ), the degree of competition in the product markets ( $s$ ), the capital-labor ratio ( $k \equiv K/L$ ) and the distribution parameter  $a$ . We observe that intensified product market competition, measured by higher elasticity of substitution between the products, increases the wage elasticity of labor demand, i.e.  $\eta_s > 0$ . More intense product market competition makes it harder for the firms to survive with higher wages and thus increased competition makes the firms' employment decisions more sensitive to changes in the wage rate. This feature holds true also in the case of Cobb-Douglas production function (see equation (14b)).<sup>5</sup> When we approach a situation with perfect competition in the product

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<sup>5</sup> There is empirical evidence according to which product market regulation has decreased and thereby competition increased in OECD countries during the 1990s (for evidence, see Nicoletti, Bassanini, Ernst, Jean, Santiago and Swaim (2001)). Gersbach (2000) summarizes three mechanisms (lower mark-ups, higher total factor productivity and expanded sets of product varieties), through which reductions in product market imperfections might enhance employment. Blanchard and Philippon (2004) have constructed a model to explore the effects of intensified product market competition when labor unions learn slowly about structural changes in the economic environment and when trust plays an important role in the labor market.

markets (as  $s \rightarrow \infty$ ) the wage elasticity of labor demand converges to  $\sigma \left( 1 + \frac{a}{1-a} k^{\frac{1-\sigma}{\sigma}} \right)$ , which reduces to  $1/(1-a)$  in the Cobb-Douglas case.

Next we ask, what is the effect of the capital-labor ratio  $k$  on the wage elasticity of labor demand? This is an important question as this wage elasticity plays an important role when evaluating the relationship between the negotiated wage and the capital stock. It is also an interesting issue because, for example, the competitiveness of the capital markets and thereby the size of the capital stock will affect the capital intensity  $k$ . Differentiating (14a) with respect to  $k$  yields

$$\eta_k = \frac{\frac{1-a}{a} \left( \frac{(\sigma-1)(\sigma-s)}{s} \right) k^{-\frac{1}{\sigma}}}{\left[ \frac{\sigma}{s} + \frac{1-a}{a} k^{\frac{\sigma-1}{\sigma}} \right]^2} \quad (15)$$

where  $s > 1$ . From (15) we infer the following properties: (i) Under gross complementarity between capital and labor ( $\sigma < 1$ ) higher capital intensity increases the wage elasticity of labor demand. (ii) The same happens under gross substitutability ( $\sigma > 1$ ) as long as the elasticity of substitution between products ( $s$ ) is lower than the elasticity of substitution between capital and labor in the production function. (iii) Under gross substitutability ( $\sigma > 1$ ) the wage elasticity is a decreasing function of the capital intensity if the elasticity of substitution between products ( $s$ ) is higher than the elasticity of substitution between capital and labor  $\sigma$  in the production function.

Case (iii) seems to be more plausible than case (ii) because empirical estimates of  $\sigma$  are never far above one, whereas available estimates of mark-ups imply that  $s$  is significantly higher. In fact, empirical evidence suggests roughly that the mark-ups lie in the range between 1.1 and 1.5 (see e.g. Roeger (1995) and Martins, Scarpetta and Pilat (1996)). Mark-ups in this range would be consistent with an assumption that  $s \geq 3$ . In what follows we will therefore assume that  $s > \sigma$ .

With an exogenous capital intensity and for  $s > \sigma$  we can summarize our findings in

**Proposition 2** *Intensified product market competition will increase the wage elasticity of labor demand. Higher capital intensity will increase (decrease) the wage elasticity of labor demand when the elasticity of substitution between labor and capital is smaller (larger) than one.*

From Proposition 2 we can conclude that the technological elasticity of substitution between the production factors is of primary importance for the relationship between capital intensity and the wage elasticity of labor demand. According to Proposition 2, when capital and labor are ‘gross complements’ ( $\sigma < 1$ ), higher capital intensity will increase the wage elasticity of labor demand due to the fact that higher capital intensity will raise the labor share. Under ‘gross substitutability’ ( $\sigma > 1$ ) between capital and labor the reverse happens, i.e. higher capital intensity will decrease the wage elasticity of labor demand due to the fact that higher capital intensity now will decrease the labor share (see also Koskela and Schöb (2002), where it is demonstrated how the capital cost with endogenous capital intensity affects the wage elasticity of labor demand when  $\sigma \neq 1$ ).

Finally, (14b) reveals the following result in the Cobb-Douglas case

**Corollary 1:** *The wage elasticity of labor demand is independent of the capital intensity in the case of a Cobb-Douglas production function.*

Corollary 1 verifies the conventional assumption, whereby there is no relationship between wage elasticity and investment under circumstances with Cobb-Douglas production functions due to the fact that the labor share is independent of capital intensity. Thus, this type of production function eliminates the potential channel through which credit market behavior might impact on the wage elasticity via the determination of the capital stock.

#### **IV. Wage Determination via Nash Bargaining**

We now turn to look at the stage of wage determination and we continue to consider the capital stock  $K$  as given. We apply the Nash bargaining solution within the context of the ‘right-to-manage’ approach according to which employment is unilaterally determined by the firms. The wage bargaining takes

place in anticipation of optimal price and employment decisions by the firms. Following the Nash bargaining approach the firm and the labor union negotiate with respect to the wage so as to solve the optimization problem

$$\max_w \Omega = [L^*(w-b)]^\beta [pR(K, L^*) - wL^*]^{1-\beta} \quad (16)$$

subject to  $\pi_L = 0$  and  $\pi_p = 0$ ,

where the relative bargaining power of the union is  $\beta$  and that of the firm is  $(1-\beta)$ ,  $L^*(w-b) = EU$ ,  $b$  is the (exogenous) outside option available to union members and  $\pi = pR(K, L) - wL$ . The outside options for the firm and the union are  $\pi^o = -\Delta K$  and  $U^o = Nb$ , respectively, where  $N$  is the number of labor union members and  $\Delta = 1+r$  denotes the cost of capital. Under these assumptions the necessary first-order condition for the wage determination can be written as

$$\beta \frac{U_w}{U} + (1-\beta) \frac{\pi_w}{\pi} = 0 \quad (17)$$

where

$$\frac{U_w}{U} = \frac{1}{w} \frac{[w(1-\eta(k,s)) + b\eta(k,s)]}{w-b} \quad (18a)$$

and

$$\frac{\pi_w}{\pi} = -\frac{1}{w} \frac{wL^*}{\pi} = -\frac{1}{w} \frac{pR_L L^*}{p[R - R_L L^*]} = -\frac{1}{w} \frac{a}{1-a} k^{\frac{1-\sigma}{\sigma}} \quad (18b)$$

Substituting the expressions (18a) and (18b) into the first-order condition (17) yields, after some rearrangement, the following Nash bargaining solutions for the wage rate in the case of CES (1a) and Cobb-Douglas (1b) production functions

$$w^N \Big|_{\sigma \neq 1} = \left[ 1 + \frac{\beta}{\beta(\eta(k,s) - 1) + (1-\beta) \frac{a}{1-a} k^{\frac{1-\sigma}{\sigma}}} \right] b \quad (19a)$$

and

$$w^N \Big|_{\sigma=1} = \left[ 1 + \frac{\beta}{\beta(\eta(s)-1) + (1-\beta)\frac{a}{1-a}} \right] b \quad (19b)$$

According to (19a) and (19b) the negotiated wage rate depends positively on the outside option ( $b$ ) and on the relative bargaining power of the union ( $\beta$ ), while negatively on the wage elasticity of labor demand ( $\eta$ ). According to (19a), the negotiated wage is affected by the capital-labor ratio ( $k$ ) both directly and indirectly though its impact on the wage elasticity of labor demand in a way, which is determined by whether elasticity of substitution between labor and capital is smaller or larger than one. Furthermore, the wage elasticity of labor demand depends positively on product market competition ( $s$ ) and for that reason decreased product market imperfections moderate the negotiated wage. In particular, as we approach perfect product market competition with  $s \rightarrow \infty$  in the Cobb-Douglas case, the wage rate converges towards  $[1 + \beta(1-a)/a]b = [1 + \beta/(\eta-1)]b$ , where  $\eta = 1/(1-a)$  is the wage elasticity of labor demand under perfect product market competition.

By differentiating the wage rate (19a) with respect to the capital-labor ratio we find for  $s > \sigma$  that

$$\frac{\partial w^N}{\partial k} = \frac{-\beta \left[ \beta \eta_k(k, s) + (1-\beta) \frac{1-\sigma}{\sigma} \frac{a}{1-a} k^{\frac{1-2\sigma}{\sigma}} \right]}{\left[ \beta(\eta(k, s)-1) + (1-\beta) \frac{a}{1-a} k^{\frac{1-\sigma}{\sigma}} \right]^2} \begin{cases} < 0 \\ = 0 \\ > 0 \end{cases} \text{ as } \begin{cases} \sigma < 1 \\ \sigma = 1 \\ 1 < \sigma < s \end{cases}. \quad (20)$$

The relationship (20) characterizes the capital stock as a strategic commitment device, whereby the capital stock may serve as a mechanism inducing wage moderation. The technological features summarized by the elasticity of substitution between the production factors determine whether such wage moderation actually takes place or not. The intuition for this relationship can be understood as follows: First, when  $\sigma < 1$  higher capital intensity decreases the negotiated wage rate via two channels: (1) it becomes harder for the union to extract rent in negotiations because of the induced higher wage elasticity of labor demand, and (2) a higher



capital-labor ratio increases the negative effect of the wage rate on the profit, i.e.

$\frac{\partial}{\partial k} \left( \frac{\pi_w}{\pi} \right) < 0$  when  $\sigma < 1$  and thus moderates wage formation. As (20) makes

clear, increased capital intensity will induce higher wages under  $\sigma > 1$ . The interpretation of this finding is analogous (but opposite) to the case of  $\sigma < 1$ .

We now summarize our analysis of the wage determination in

**Proposition 3** *The negotiated wage rate depends negatively on the wage elasticity of labor demand and therefore intensified product market competition will decrease the wage rate. Higher capital intensity will decrease (increase) the negotiated wage rate if the elasticity of substitution between capital and labor is smaller (larger) than one.*

Finally, if the production function is Cobb-Douglas we can replicate the Layard, Nickell and Jackman (1991) finding according to which the capital stock does not affect wage formation.

**Corollary 2** *With a Cobb-Douglas production function capital intensity will have no effect on the negotiated wage.*

The negotiated Nash wage (19a) and (19b) imply a number of interesting special cases. If all the bargaining power lies with the union ( $\beta = 1$ ), the Nash bargaining solution is simplified to the monopoly union solution

$$w^M \Big|_{\sigma \neq 1} = \frac{\eta(k,s)}{\eta(k,s)-1} b \quad \text{and} \quad w^M \Big|_{\sigma=1} = \frac{\eta(s)}{\eta(s)-1} b, \quad (20')$$

according to which the wage mark-up depends negatively on the wage elasticity of labor demand, which is a function of the capital-labor ratio  $k$  when  $\sigma \neq 1$  while it is not when  $\sigma = 1$ . Further, the wage elasticity of labor demand is an increasing function of the price elasticity of product demand  $s$ . In the opposite case with all the bargaining power concentrated to the firm ( $\beta = 0$ ), the relationship between the negotiated wage and the capital intensity disappears. In this case the negotiated wage converges to the competitive wage with  $w^C = b$ , i.e. the wage mark-up is eroded. Intuitively this seems to make sense for the following reason. The capital intensity serves as a strategic commitment device, which will affect the distribution

of the rents, achieved through bargaining, in imperfectly competitive labor markets.<sup>6</sup> Once the labor market imperfections are eroded the capital intensity can no longer play such a strategic role.

There is empirical evidence according to which higher product market competition will moderate wage formation. Nickell (1999) presents a survey of this literature, which includes, for example, Abowd and Lemieux (1993) (Canadian data), Nickell, Vainiomaki and Wadhvani (1994) (British manufacturing data) and Neven, Röller and Zhang (1999) (data from eight European airline companies) to analyze links between product market competition and union power.

## V. Product Markets, Exogenous Capital Intensity and Equilibrium Unemployment

Above we have characterized wage formation, labor demand and price setting from a partial equilibrium perspective. We now move on to explore the determinants of equilibrium unemployment in a general equilibrium framework. In this section we are interested in the relationships between the exogenous capital intensity, the intensity of competition in the product market and the equilibrium unemployment.

According to (19a) and (19b) the negotiated wage rate in industry  $i$  is of the form  $w_i^N = A_i b$ , where the mark-up factors in the cases of CES and Cobb-Douglas production functions are

$$A|_{\sigma \neq 1} = 1 + \frac{\beta}{\beta(\eta(k,s) - 1) + (1 - \beta) \frac{a}{1-a} k^{\frac{1-\sigma}{\sigma}}} \quad (21a)$$

and

$$A|_{\sigma=1} = 1 + \frac{\beta}{\beta(\eta(s) - 1) + (1 - \beta) \frac{a}{1-a}} \quad (21b)$$

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<sup>6</sup> In other contexts both the capital structure and the compensation scheme have been shown to constitute a similar type of commitment device (see e.g. Dasgupta and Sengupta (1993) and Koskela and Stenbacka (2004a), (2004b)).

These mark-up factors are, in principle, industry-specific. We impose symmetry assumptions meaning that  $A_i = A$  and  $w_i^N = w^N$  for all  $i$ . In a general equilibrium the term  $b$  should be re-interpreted as the relevant outside option, which we specify as

$$b = (1-u)w^N + uB, \quad (22)$$

where  $u$  is the unemployment rate,  $B$  captures the unemployment benefit and  $w^N$  denotes the negotiated wage rate in all identical industries (see, e.g. Nickell and Layard (1999)). Assuming a constant benefit replacement ratio  $q = B/w^N$  and substituting (22) for  $b$  into the Nash bargaining solutions (19a) and (19b) yields the equilibrium unemployment

$$u^N = \frac{1}{1-q} \left[ 1 - \frac{1}{A} \right], \quad (23)$$

where the wage mark-up  $A$  is given by (21a) for  $\sigma \neq 1$  and by (21b) for  $\sigma = 1$ .

According to (23) a higher benefit-replacement ratio,  $q$ , and a higher mark-up in the wage determination,  $A$ , will increase equilibrium unemployment. Further, from the mark-ups in the wage determination we can conclude that higher wage elasticity of labor demand will decrease equilibrium unemployment. In fact, differentiating (21a) with respect to  $s$  gives

$$A_s = - \frac{\beta^2 \eta_s}{\left[ \beta(\eta(k,s) - 1) + (1 - \beta) \frac{a}{1-a} k^{\frac{1-\sigma}{\sigma}} \right]^2} < 0, \quad (24)$$

meaning that intensified product market competition will moderate the wage mark-up in the general case  $\sigma \neq 1$ . The same qualitative result holds true also in the case with  $\sigma = 1$  as can be seen by differentiating (21b) with respect to  $s$ . Hence, intensified product market competition will, ceteris paribus, decrease equilibrium unemployment because  $\eta_s > 0$  and  $\frac{\partial u^N}{\partial \eta} < 0$ .

As for the impact of the capital-labor ratio on equilibrium unemployment we initially observe under  $s > \sigma$  that

$$A_k = - \frac{\beta \left[ \beta \eta_k + (1 - \beta) \frac{1 - \sigma}{\sigma} \frac{a}{1 - a} k^{\frac{1 - 2\sigma}{\sigma}} \right]}{\left[ \beta (\eta(k, s) - 1) + (1 - \beta) \frac{a}{1 - a} k^{\frac{1 - \sigma}{\sigma}} \right]^2} \begin{cases} < 0 \\ = 0 \\ > 0 \end{cases} \text{ as } \begin{cases} \sigma < 1 \\ \sigma = 1 \\ 1 < \sigma < s \end{cases}. \quad (25)$$

(25) offers a characterization of the capital stock as a strategic commitment device with employment effects. Because it holds true that  $\frac{\partial w_k^N}{\partial k} = A_k b$ , we can explore the effect of the capital intensity on equilibrium unemployment by combining (20) and (25). The relationship between the negotiated wage and the capital intensity was characterized in Proposition 3. According to Proposition 3 more intense product market competition will, ceteris paribus, moderate the negotiated wages and thereby decrease equilibrium unemployment, while the relationship between capital intensity, wage formation and thereby the relationship between capital intensity and equilibrium unemployment is more complicated. More specifically, it depends on the size of the elasticity of substitution between production factors, on the degree of product market competition, measured by the price elasticity of demand as well as on the relative sizes of these two parameters.

Our findings concerning the determinants of equilibrium unemployment under exogenous capital intensity can now be summarized in

**Proposition 4** *Increased product market competition will reduce equilibrium unemployment. Higher capital intensity will reduce equilibrium unemployment when the elasticity of substitution between capital and labor is smaller than one while the reverse happens when it is higher than one.*

According to Proposition 4 the effect of capital intensity on equilibrium unemployment depends on whether the elasticity of substitution between labor and capital exceeds or falls short of one. In any case, as the empirical studies cited in the introduction unanimously seem to reject the Cobb-Douglas specification, Proposition 4 predicts that there is a systematic relationship between equilibrium unemployment and capital intensity. As the existing empirical studies cited in the

introduction all report estimates according to which the elasticity of substitution is below one for the U.S. economy our model would imply the prediction of a negative relationship between equilibrium unemployment and the capital intensity for this economy.

Finally, if we were to accept the Cobb-Douglas production function our model would reproduce the Layard, Nickell and Jackman (1991) finding according to which the capital stock does not affect wage formation.

**Corollary 3** *With a Cobb-Douglas production function equilibrium unemployment is independent of the capital intensity.*

Our results regarding the relationship between labor market imperfections, product market imperfections, investments and equilibrium unemployment are related to a few recent research contributions. Blanchard and Giavazzi (2003) and Spector (2004) have earlier theoretically studied the employment consequences of product market competition and deregulation within a bargaining framework. Ebell and Haefke (2003) apply a dynamic matching model to explore the dynamic relationship between product market competition and equilibrium unemployment. In contrast to Blanchard and Giavazzi (2003) and Spector (2004), Ebell and Haefke (2003) make use of a Cournot model where the number of firms competing in each industry measures the intensity of product market competition. All these contributions, however, abstract from the determination of capital investment and, in particular, from its potential implications for employment by assuming either the linear or Cobb-Douglas production function with labor being the only production factor. As our study makes clear, the characterization of equilibrium unemployment is bound to be incomplete under such restrictions of the models. As we have shown, the interactions between labor market imperfections, product market imperfections and the capital intensity have important implications for the wage formation, and thereby for equilibrium unemployment.

## **VI. Endogenous Capital Intensity and Equilibrium Unemployment: The Long-Run Perspective**

So far we have restricted ourselves to a short run or medium run perspective, where the capital stock has been considered exogenous. In this section we now turn

to explore the initial stage of the decision making structure. At this stage firms determine the capital investments and thereby the intensity  $k = K/L$ . We are particularly interested in characterizing how the interest rate and labor and product market imperfections impact on the capital investments and on the associated equilibrium unemployment in the long run.

We impose no imperfections on the capital market. Thus, in the long run the capital intensity is determined so as to generate zero profits. However, the firms have rational expectations regarding the subsequent outcomes with respect to wage negotiation, employment and price setting and the long-run investment decisions internalize the effects of the capital intensity on wages, employment and prices.

The long-run capital stock is determined by the equilibrium condition

$$\pi = p_i R(K_i, L_i^*) - w_i^N L_i^* - \Delta K_i = 0, \text{ for all } i \quad (26)$$

$$\text{s.t. } \Omega_w = 0, \pi_{L_i}^i = 0 \text{ and } \pi_{p_i}^i = 0.$$

The constraints capture that the capital stock is set in anticipation of the subsequent determination of wages, employment and prices. In (26)  $\Delta = 1 + r$  denotes the cost of capital, which we assume to be exogenously given.

Substituting the labor demand, determined by (12), into the profit function in the left hand side of (26) and dropping the firm-specific index we can write the profit function as  $\pi = \frac{w}{R_L} R - w^N L^* - \Delta K$ . Further, by exploiting the property that

$$\frac{R}{R_L} = L \left[ \frac{1-a}{a} k^{\frac{\sigma-1}{\sigma}} + 1 \right]$$

for the CES production function (1) we see that the profit

function associated with (26) can be rewritten as

$$\pi = w^N L^* \left[ \frac{1-a}{a} k^{*\frac{\sigma-1}{\sigma}} + 1 \right] - w^N L^* - \Delta K.$$

By further dividing all the terms by  $L^*$  it

follows that the equilibrium condition (26) can be expressed in terms of the endogenous capital intensity,  $k^*$ , according to

$$\pi = w^N \frac{1-a}{a} k^{*\frac{\sigma-1}{\sigma}} - \Delta k^* = 0. \quad (27)$$

From (27) we can see that the equilibrium capital intensity has to satisfy

$$w^N \frac{1-a}{a} k^{*\frac{1}{\sigma}} - \Delta = 0 \Leftrightarrow k^* = \left( \frac{1-a}{a} \frac{w^N}{\Delta} \right)^\sigma . \quad (28)$$

(28) defines the equilibrium capital intensity as a function of effective cost of capital ( $\Delta$ ), and via the Nash bargaining wage  $w^N$  in (19a), as a function of the measure of product market competition ( $s$ ) and the relative bargaining power of the trade union ( $\beta$ ) so that we have  $k^* = k^*(\Delta, s, \beta)$ . By differentiation of (28) we find that

$$k_\Delta^* = -\sigma \frac{k^*}{\Delta} < 0, \quad k_s^* = \sigma \frac{k^* w_s^N}{w^N} < 0, \quad k_\beta^* = \sigma \frac{k^* w_\beta^N}{w^N} > 0 . \quad (29)$$

Hence, the equilibrium capital intensity is a decreasing function of the effective costs of capital and the intensity of product market competition, whereas it is an increasing function of relative bargaining power of trade union. These comparative statics properties can be shown to hold also in the case of a Cobb-Douglas production function with  $\sigma = 1$  (1b).

We summarize our findings regarding the equilibrium capital intensity in

**Proposition 5** *The equilibrium capital intensity depends negatively on the degree of product market competition and on the effective costs of capital, whereas it depends positively on the bargaining power of the trade union.*

The negative relationship in (29) between the equilibrium capital intensity and the degree of product market competition captures the idea that increased product market competition simply diminishes the available returns associated with the investment. This relationship seems to be consistent with the empirical evidence presented by Alesina et al (2003). These authors used OECD data to study how various measures of regulation in the product market, concerning in particular entry barriers, are related to investment behavior. According to their findings product market deregulation seems to have a statistically significant negative effect on

investment behavior, *ceteris paribus*. It should, however, be remarked that the analysis of Alesina et al (2003) abstracts from labor market frictions. The positive relationship in (29) between the labor market imperfections and the equilibrium investment captures the intuition that increased bargaining power of the labor union decreases the relative attractiveness of labor as a production factor. Therefore, the optimal response of the firm is to increase the capital investment.

We next characterize the equilibrium unemployment in the long run with endogenous capital intensity. We are particularly interested in exploring the effects of the degree of product market competition, the bargaining power of the trade unions and the interest rate on equilibrium unemployment. For that purpose we essentially have to study the effects of these parameters on the wage mark-up.

The negotiated wage mark-up associated with the equilibrium capital intensity is given by

$$A = 1 + \frac{\beta}{\beta(\eta(k^*(\Delta, s, \beta)) - 1) + (1 - \beta) \frac{a}{1 - a} k^*(\Delta, s, \beta)^{\frac{1 - \sigma}{\sigma}}}. \quad (30)$$

Now we study the long-run effects of the interest rate as well as product and labor market imperfections on the wage mark-up under endogenous capital intensity.<sup>7</sup> We first explore the impact of the interest rate on the wage mark-up. By differentiating (30) we can see that the effect of a change of the effective cost of capital is given by  $A_k \cdot k_\Delta^*$ , where  $A_k$  is characterized in (25). Clearly, in the long run this effect is now opposite in sign compared with (25) due to the property that  $k_\Delta^* < 0$ . Hence, a lower effective cost of capital, associated, for example, with more intense credit market competition as a result of financial market reforms, reduces equilibrium unemployment when the elasticity of substitution between labor and capital is smaller than one, while the reverse happens when it is higher than one.

We can formulate this feature in

**Proposition 6** *The long-run equilibrium unemployment under endogenous capital intensity is an increasing (decreasing) function of the interest rate when the*

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<sup>7</sup> Blanchard and Giavazzi (2003, p. 893) call for a similar extension in a related context.



*elasticity of substitution between capital and labor is lower (higher) than one, while the interest rate has no effect on equilibrium unemployment in the case of a Cobb-Douglas production function.*

Earlier we showed that intensified product market competition will reduce equilibrium unemployment when the capital intensity is exogenously given. We next ask the following question: What is the long-run effect of intensified product market competition, when this affects the mark-up and thereby equilibrium unemployment both directly via the wage elasticity of labor demand and indirectly by changing the wage rate and thereby the capital intensity, which in turn affects the mark-up both directly and through the wage elasticity of labor demand?

Differentiating (30) with respect to  $s$  gives after some rearrangements<sup>8</sup>

$$A_s = \beta \frac{-\beta \eta_s - \beta \eta_{k^*} k_s^* - (1-\beta) \frac{a}{1-a} \frac{1-\sigma}{\sigma} k_s^{*1-2\sigma} k_s^*}{\left[ \beta(\eta-1) + (1-\beta) \frac{a}{1-a} k_s^{*1-\sigma} \right]^2}. \quad (31)$$

where  $\eta = \eta(k^*, s)$ . As delineated in (31), we can identify three channels whereby the intensity of product market competition affects the long-run mark-up: (1) a direct effect via the change in the wage elasticity of labor demand ( $-\beta \eta_s$ ) (cf. (24)), (2) an indirect effect via the wage elasticity of labor demand ( $-\beta \eta_{k^*} k_s^*$ ) due to a change in capital intensity and (3) an indirect effect via the change in the capital intensity for the effect of the wage rate on the profit ( $-(1-\beta) \frac{1-\sigma}{\sigma} k_s^{*1-2\sigma} k_s^*$ ). The direct effect is always negative, because  $\eta_s > 0$ , while the two indirect effects may be negative or positive depending on the size of  $\sigma$ . We know from (29) that  $k_s^*$  is always negative, while from (15) we see that  $\eta_{k^*}$  is negative provided that  $\sigma \geq 1$ . It follows that the first indirect effect is always negative when  $\sigma \geq 1$ . As for the remaining indirect effect we can observe that it is always negative when  $\sigma \geq 1$ . Therefore, when  $\sigma \geq 1$ , each of the three effects drive

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<sup>8</sup> We can see that this is reduced to (24) in the absence of the investment effects.

in the same direction and intensified product market competition unambiguously decreases the negotiated wage mark-up in the labor market and thereby reduces equilibrium unemployment under endogenous capital intensity. Notice that this long-run impact of product market competition on equilibrium unemployment also holds true in the special case of Cobb-Douglas production function.

When the elasticity of substitution between labor and capital is less than one ( $\sigma < 1$ ), intensified product market competition does not necessarily result in a decrease in the negotiated wage mark-up in the labor market. In this situation only the direct effect is negative, while the indirect effects tend to increase the negotiated wage mark-up, because  $k_s^*$  is always negative, while  $\eta_{k^*}$  is positive when  $\sigma < 1$ . Whether the two indirect effects outweigh the direct effect depends on the parameters of the model. Extensive numerical experiments with different parameter values indicate that there is a critical value  $\hat{\sigma} \in [0,1]$  such that  $A_s < 0$  ( $A_s \geq 0$ ) whenever  $\sigma > \hat{\sigma}$  ( $\sigma \leq \hat{\sigma}$ ).

We collect our results to the following proposition.

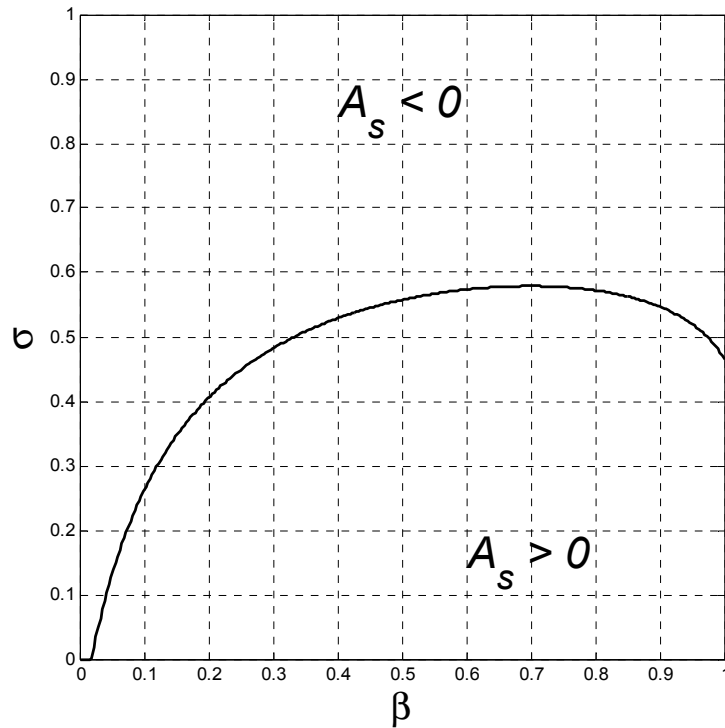
**Proposition 7** *There is a critical threshold value  $\hat{\sigma} < 1$  such that the long-run equilibrium unemployment is a decreasing function of the intensity of product market competition when  $\sigma > \hat{\sigma}$ .*

Proposition 7 indicates that if the elasticity of substitution between labor and capital is less than one, the consequences of tighter product market competition for the wage mark-up and unemployment are not clear. It is of particular interest to characterize those circumstances under which intensified product market competition induces higher wage markups and, thus, a higher unemployment rate.

Figure 2 illustrates how the critical value  $\hat{\sigma}$  depends on the bargaining power of the labor union,  $\beta$ . Notice that the critical value tends to be very low when the bargaining power is close to zero, while it rises rather sharply when  $\beta$  increases from zero. This observation is quite natural, because a stronger labor union is able to push wages up, while it is harder for the firms to off-set these pressures with higher capital-labor ratios, i.e. to replace labor with capital, when  $\sigma$  is sufficiently low. A sufficiently small  $\sigma$  serves as a technological obstacle against substituting

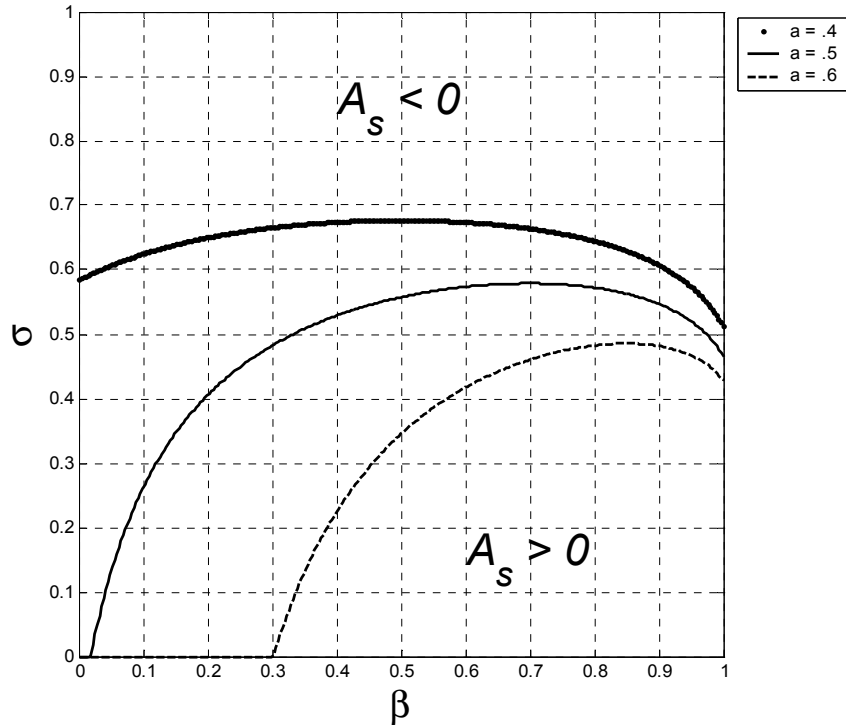
labor with capital. When this technological obstacle is strong ( $\sigma$  low) and when the bargaining power of the union undermines the investment incentives of the firm the total effect of intensified product market competition may increase the wage-mark up and thereby harm employment.

Interestingly, the critical value  $\hat{\sigma}$  is not necessarily a monotonic function of  $\beta$ . When the bargaining power approaches one, eventually the critical value  $\hat{\sigma}$  may start to decrease. This phenomenon indicates that the effectiveness of the capital-labor ratio as an instrument of the firm to prevent wages from rising becomes efficient when the labor union becomes very strong. Thus with very strong labor market imperfections ( $\beta$  sufficiently close to one), a lower elasticity of substitution is required for increased product market competition to result in higher wage mark-ups and higher unemployment rates.



**Figure 2:** Critical  $\sigma$  above (below) which intensified product market competition decreases (increases) the wage mark-up for the parameter combination with  $s = 10$ ,  $\Delta = 1.03$ , and  $a = 0.5$ .

Figure 3 further illustrates how the critical value  $\hat{\sigma}$  shifts when the distribution parameter  $a$  changes. In general, the larger is  $a$  (the labor share of production), the smaller is the region where  $A_s$  is positive.<sup>9</sup> This observation means that intensified product market competition is a stronger device for inducing wage moderation when the labor plays a more significant role relative to capital as a production factor.



**Figure 3:** The effect of the parameter  $a$  for the critical  $\sigma$  above (below) which intensified product market competition decreases (increases) the wage mark-up for the parameter combination with  $s = 10$  and  $\Delta = 1.03$ .

Finally, we explore the long-run effect of the bargaining power of the labor union on equilibrium unemployment under endogenous capital intensity. Now, differentiating (30) with respect to  $\beta$  yields, after some rearrangements,

<sup>9</sup> We were able to verify this same pattern with a series of numerical experiments with alternative parameter values.

$$A_\beta = \frac{\frac{a}{1-a} k^{*\frac{1-\sigma}{\sigma}} - \beta^2 k_\beta^* \eta_k^* - \beta(1-\beta) \frac{a}{1-a} \frac{1-\sigma}{\sigma} k^{*\frac{1-2\sigma}{\sigma}}}{\left[ \beta(\eta-1) + (1-\beta) \frac{a}{1-a} k^{*\frac{1-\sigma}{\sigma}} \right]^2}. \quad (32)$$

Again there are three channels of influence whereby the parameter  $\beta$  affects the long-term mark-up: (1) a direct effect via the change in the bargaining power ( $\frac{a}{1-a} k^{*\frac{1-\sigma}{\sigma}}$ ), (2) an indirect effect through the shift in the wage elasticity of labor demand produced by a change in the capital intensity ( $-\beta^2 \eta_k^* k_\beta^*$ ) and (3) an indirect effect of the wage rate on the profit via the induced change of the capital intensity ( $-\beta(1-\beta) \frac{1-\sigma}{\sigma} k^{*\frac{1-2\sigma}{\sigma}} k_\beta^*$ ). A priori, we would expect that more imperfect labor markets yield higher wage mark-ups also in the long run, which would imply a higher rate of equilibrium unemployment. In fact, as is shown in Appendix A, this turns out to be the case, but it is not a self-evident result from a technical point of view as the direction of the indirect effects is opposite to the direct effect when  $\sigma < 1$ .

We can formulate

**Proposition 8** *The long-run equilibrium unemployment under endogenous capital intensity is always an increasing function of the relative bargaining power of the labor unions.*

Thus, we have established the following general result. Even though increased bargaining power of the labor union will stimulate the investment incentives of firms in the long run, the induced increase in the equilibrium capital stock will not be large enough from the point of view of the total employment effects so as to outweigh the negative direct employment effects of higher negotiated wages. This suggests that the expansion of the capital stock induced by increased labor market imperfections can never be large enough so as to promote employment in the long run.

## VII. Conclusions

The employment consequences of intensified competition and deregulation in product markets have been analyzed to some extent in the recent literature. However, in this literature the potential role of investments has been neglected as these studies have postulating a production function with labor as the only production factor either in a linear (see Blanchard and Giavazzi (2003), Ebell and Haefke (2003)) or in a Cobb-Douglas form (see Spector (2004)). Our starting point has been similar to these studies in that we have assumed imperfect competition in the product and labor markets, but importantly we have generalized these models by assuming a more general and realistic CES-type production function, in which the elasticity of substitution between capital and labor can be different from one. This has established a new and richer framework for studying the interaction effects between imperfections in labor and product markets and long-term investment decisions for the determination of equilibrium unemployment in the long run.

We have shown the following new results. Under exogenous capital intensity – which can be interpreted to offer either a short-run or a medium-run perspective for structural unemployment analysis – reduced product market imperfections, *ceteris paribus*, will always decrease equilibrium unemployment. The effect of capital intensity is more complex. The capital intensity serves as a strategic commitment device with which the owners of the firms can affect the distribution of rents achieved through wage bargaining in imperfectly competitive labor markets. In fact, the negotiated wage rate decreases, and therefore also equilibrium unemployment declines, as a result of higher capital intensity when the elasticity of substitution between capital and labor is less than one, while the reverse happens when the elasticity of substitution is higher than one. This is due to the fact that in the former (latter) case higher capital intensity will increase (decrease) wage elasticity of labor demand. In the special case with a Cobb-Douglas production function the relationship between capital stock and equilibrium unemployment will vanish. When the negotiated wage converges to the competitive rate the capital intensity does no longer serve as a strategic commitment device, which could affect the distribution of the rents. Thus, in the absence of labor market imperfections the capital intensity can have no effect on equilibrium unemployment.

After demonstrating how labor and product market imperfections affect the equilibrium capital intensity in the long-run, we investigated the determinants of equilibrium unemployment from the long-run perspective. Higher interest rates will increase (decrease) equilibrium unemployment when the elasticity of substitution between capital and labor is lower (higher) than one. Furthermore, we explored the qualitative properties of equilibrium unemployment in the long run with a particular focus on the total long-run effects of labor and product market imperfections on equilibrium unemployment. These total long-run effects of labor and product market imperfections on equilibrium unemployment incorporate both direct effects and indirect mechanisms through the effects on wage formation and long-run capital investments. We have shown that the long-run equilibrium is always an increasing function of the relative bargaining power of the labor unions, whereas there is, in general, not a monotonic relationship between the long-run unemployment and the intensity of product market competition. There is, however, a critical threshold, below one, of the elasticity of substitution between capital and labor such that the long-run equilibrium unemployment is a decreasing function of the intensity of product market competition when the elasticity exceeds this threshold.

Our model can clearly be extended in several dimensions. Throughout the analysis we have focused on a homogeneous labor force. However, it could be very interesting to separate the labor force into a high-skill and low-skill segment with different elasticities of labor demand due to the fact that elasticity of substitution between capital and skilled labor will likely differ from the elasticity of substitution between capital and unskilled labor.<sup>10</sup> Within such a richer context it might be possible to characterize qualitatively different interaction patterns between and capital investments and employment across the different labor market segments. Also, our model has abstracted from all aspects of taxation of production factors.

Our new theoretical findings also raise interesting empirical issues for future research. In particular, our analysis highlights the importance of obtaining reliable estimates for the elasticity of substitution between labor and capital inputs,

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<sup>10</sup> Goldin and Katz (1998) have analyzed the origins of technology-skill complementarity both theoretically and empirically. Krusell et.al (2000) have provided a theoretical framework to explain the skill premium in terms of relative wage of skilled and unskilled labor.

because, as we have emphasized throughout this analysis, several significant properties of the long-run equilibrium unemployment are contingent on this elasticity. Moreover, the relationship between long-run equilibrium unemployment and product market competition depends on other parameters as well, which is an important topic for empirical research.

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## **Appendix A: Derivation of wage elasticity of labor demand**

By using the production function we can write the wage elasticity of labor demand as follows

$$\eta(k, s) = -\frac{L_w w}{L} = -\frac{pR_L}{L[pR_{LL} + p_L R_L]} = -\frac{1}{L \frac{R_{LL}}{R_L} + L \frac{p_L}{P}}, \quad (\text{A.1})$$

where the specification (1a) of the text implies  $k = \frac{K}{L}$ ,  $R_L = X^{\frac{1}{\sigma-1}} a L^{-\frac{1}{\sigma}}$ ,

$$X = (1-a)K^{\frac{\sigma-1}{\sigma}} + aL^{\frac{\sigma-1}{\sigma}} \quad \text{and} \quad R_{LL} = -\frac{1}{\sigma} a X^{\frac{1}{\sigma-1}} L^{-\frac{1}{\sigma-1}} + \frac{1}{\sigma} X^{\frac{1}{\sigma-1}-1} a^2 L^{\frac{2}{\sigma}}.$$

Moreover, since it holds that  $p_i = \left[ X^{\frac{\sigma}{\sigma-1}} \frac{P^{1-s}}{M} \right]^{\frac{1}{s}}$  and  $\frac{\partial p_i}{\partial L_i} = -\frac{1}{s} p_i X^{-1} a L^{-\frac{1}{\sigma}}$  we

get

$$L \frac{p_L}{p} = -\frac{1}{s} X^{-1} a L^{\frac{\sigma-1}{\sigma}} \quad (\text{A.2})$$

and

$$\frac{LR_{LL}}{R_L} = \frac{-\frac{1}{\sigma} a X^{\frac{1}{\sigma-1}} L^{-\frac{1}{\sigma}} + \frac{1}{\sigma} X^{\frac{1}{\sigma-1}-1} a^2 L^{\frac{2-\sigma}{\sigma}}}{X^{\frac{1}{\sigma-1}} a L^{-\frac{1}{\sigma}}} = \frac{1}{\sigma} \left[ X^{-1} a L^{\frac{\sigma-1}{\sigma}} - 1 \right] \quad (\text{A.3})$$

Using (A.2) and (A.3) the wage elasticity of substitution can be written as

$$\eta(k, s) = \frac{-1}{\frac{1}{\sigma} \left[ X^{-1} L^{\frac{\sigma-1}{\sigma}} - 1 \right] - \frac{1}{s} X^{-1} L^{\frac{\sigma-1}{\sigma}}} = \frac{\sigma \left( 1 + \frac{1-a}{a} k^{\frac{\sigma-1}{\sigma}} \right)}{\frac{\sigma}{s} + \frac{1-a}{a} k^{\frac{\sigma-1}{\sigma}}} \quad (\text{A.4})$$

**Q.E.D.**

## Appendix B: Proof of Proposition 8

We have to prove that  $A_\beta$  given by (32) satisfies that  $A_\beta \geq 0$ . We separate the proof into two separate parts, one for  $\sigma \geq 1$  and one for  $\sigma < 1$ .

(1)  $\sigma \geq 1$ : The sign of (32) is determined by the numerator, which consists of three effects: (a) the direct effect  $(\frac{a}{1-a} k^{\frac{1-\sigma}{\sigma}})$ , (b) the indirect effect through the shift in the wage elasticity of labor demand produced by a change in the capital intensity  $(-\beta^2 \eta_k^* k_\beta^*)$  and (c) an indirect effect via the induced change of the capital intensity  $(-\beta(1-\beta) \frac{1-\sigma}{\sigma} k^{\frac{1-2\sigma}{\sigma}} k_\beta^*)$ . The direct effect is always positive. Recalling from (29) that  $k_\beta^*$  is always positive, it follows that both the indirect effects are also positive whenever  $\sigma \geq 1$ , because then it holds that  $\eta_k^* > 0$ .

(2)  $\sigma < 1$ : In this case it is not straightforward to see that the condition  $A_\beta \geq 0$  holds, because when  $\sigma < 1$  we have  $\eta_k < 0$  and  $1-\sigma < 0$  so that both of the indirect effects in (32) are negative. For the result  $A_\beta \geq 0$  to hold, the (positive) direct effect must exceed the (negative) indirect effects in (32). In order to show that this indeed holds true we present a proof by contradiction.

Suppose an antithesis that  $A_\beta < 0$ , which means that

$$\beta^2 k_\beta^* \eta_k^* + \beta(1-\beta) \frac{a}{1-a} \frac{1-\sigma}{\sigma} k^{\frac{1-2\sigma}{\sigma}} \geq \frac{a}{1-a} k^{\frac{1-\sigma}{\sigma}}.$$

By re-arrangement and taking (29) into account this condition can be expressed according to

$$\beta \frac{w_\beta^N}{w^N} \left[ (1-\sigma)(1-\beta) + \beta \sigma k^{\frac{-\sigma}{1-\sigma}} \frac{(\frac{1-a}{a})^2 \left( \frac{(\sigma-1)(\sigma-s)}{s} \right)}{\left[ \frac{\sigma}{s} + \frac{1-a}{a} k^{\frac{\sigma-1}{\sigma}} \right]^2} \right] > 1.$$

However, since  $w^N = Ab$  the antithesis would imply that  $w_\beta^N < 0$ . But, this would lead to a contradiction, since the factor inside the bracket in the inequality above is positive whenever  $\sigma < 1$ . Consequently, it must hold true that  $A_\beta \geq 0$  whenever  $\sigma < 1$ .

**Q.E.D.**