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ABSTRACT

Unionization Structures and Firms’ Incentives for Productivity Enhancing Investments[*]

by Justus Haucap and Christian Wey

This paper examines how unionization structures that differ in the degree of wage centralization affect firms' incentives to increase labor productivity. We distinguish three modes of unionization with increasing degree of centralization: (1) “Decentralization” where wages are determined independently at the firm-level, (2) “coordination” where an industry union sets individual wages for all firms at the firm-level, and (3) “centralization” where a uniform wage rate is set for the entire industry. We show that firms' investment incentives are largest under complete centralization. However, investment incentives are non-monotone in the degree of centralization so that “decentralization” carries higher investment incentives than “coordination.” Depending on the innovation outcome, workers' wage bill is maximized under “centralization” if firms' productivity differences remain small. Otherwise, workers prefer an intermediate degree of centralization, which holds innovative activity down at its lowest level. Labor market policy can spur innovation by either decentralizing unionization structures or by imposing non-discrimination rules on monopoly unions.

Keywords: Unions, Oligopoly, Innovation, Productivity, Wage-Setting Centralization, Labor Market Flexibility

JEL Classification: D43, J50, K31, L13

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ZUSAMMENFASSUNG

Gewerkschaftssysteme und die Anreize der Unternehmen zur Produktivitätssteigerung

Diese Arbeit untersucht den Einfluß unterschiedlicher Gewerkschaftssysteme auf die Anreize von Unternehmen, ihre Arbeitsproduktivität zu erhöhen. Wir unterscheiden zwischen drei Gewerkschaftsstrukturen mit zunehmendem Zentralisierungsgrad: 1.) „Dezentrale Lohnsetzung“, bei der Löhne ohne zentrale Koordination auf Unternehmensebene bestimmt werden, 2.) „koordinierte Lohnsetzung“, bei der eine Industriegewerkschaft die Lohnforderungen gegenüber einzelnen Arbeitgebern koordiniert und 3.) „zentralisierte Lohnsetzung“, bei der ein einheitlicher Lohnsatz für die gesamte Industrie bestimmt wird. Wir zeigen, daß die Investitionsanreize der Unternehmen bei „zentralisierter Lohnsetzung“ am stärksten sind. Die Investitionsanreize sind allerdings nicht monoton im Zentralisierungsgrad: „Dezentralisierte Lohnsetzung“ führt zu stärkeren Investitionsanreizen als „koordinierte Lohnsetzung“. Die Lohnsumme ist in einem zentralisierten Gewerkschaftssystem maximal, solange die Innovationen hinreichend „klein“ sind, so daß die Unterschiede in der Produktivität zwischen den Unternehmen gering bleiben. Bei „großen“ Innovationen bevorzugen Arbeitnehmer hingegen eine „koordinierte Lohnsetzung“, wodurch die Innovationstätigkeit der Unternehmen auf ihr niedrigstes Niveau gedrückt wird. Arbeitsmarktpolitik kann die Innovationsanreize entweder durch eine Dezentralisierung der Lohnsetzung oder durch Diskriminierungsverbote für Monopolgewerkschaften erhöhen.

1 Introduction

How unions affect firms' performance, innovation and labor productivity is a highly controversial issue (for a survey see, e.g., Flanagan 1999). On the one hand, unions are argued to hurt firms as unionization may increase wage demands and, thereby, firms' labor costs (see, e.g., Oswald 1985, Farber 1986, or Hirsch 1991). On the other hand, unions are regarded as part of a constructive labor market regime which smoothens industrial relations, thereby promoting labor productivity and lowering average costs (see Freeman and Medoff 1984). In general though, it is not the mere existence of unions that is decisive for firms' performance, but rather the specific mode of labor market organization (see Calmfors and Driffill 1988, Soskice 1990, and Layard et al. 1991).

Wage setting differs substantially between countries.[1] A salient dimension that differentiates national unionization structures is the degree of wage-setting centralization (see, e.g., Calmfors and Driffill 1988, Moene and Wallerstein 1997, Flanagan 1999, and Wallerstein 1999).[2] At the industry level, a decentralized wage setting structure is commonly contrasted with a completely centralized wage setting structure. While in the former case, wages are set between a single employer and a firm-level union, in the latter case an industry union negotiates a standard wage for the entire industry.

Among the different modes of labor market organization, the more centralized labor market institutions have come under attack in the policy debate over labor market organization and economic performance. A commonly held view is that wage rigidities that do not account for local conditions are generally bad for overall economic performance (see, for example, Nickell 1997 and Siebert 1997), so that any move towards more decentralized, and hence, more flexible structures is good for the economy. Consistent with this view, the OECD Jobs Study (OECD 1996, p. 15) recommends to "make wage and labour costs more flexible by removing restrictions that prevent wages from reflecting local conditions (...).”

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[1] As labor market organization differs substantially between countries, regions, and industries, there exists a large literature about the possible key characteristics which are crucial for the relative performance of different labor market organizations. For comparisons of countries' labor market institutions see, e.g., Nickell (1997), OECD (1997, chapter 3), Blau and Kahn (1999), and Wallerstein (1999).

[2] The notion of centralization has been used by Calmfors and Driffill (1988) to argue that differences in national unionization structures can explain macroeconomic performance. In their work the notion of centralization refers to the degree to which coalitions are created across unions, firms or industries. Accordingly, enterprise wage-setting between one firm and its respective union is the most decentralized form of a (collective) wage agreement, while wage centralization increases the more firms a single union can bring under a single wage-tariff agreement where complete centralization is reached if the entire economy falls under the collective wage agreement. In contrast to this approach, we will confine our analysis to the industry level.

Given this policy recommendation, tendencies to introduce more flexibility into centralized wage systems have given rise to intermediate structures, where wage setting remains highly coordinated at the industry level but where adjustments to local conditions can be made at the firm-level as well. For example, in Germany collective wage agreements between industry unions and employer associations have started to contain so-called “opting out clauses” according to which firms are allowed to pay wages below the collectively agreed rate if they face economic hardships.[3] Moreover, even wage-setting under the auspices of an industry union can allow for considerable wage differentials between firms.[4] Trends towards less centralized wage setting institutions can also be observed in other countries as, e.g., Denmark, Sweden, Australia, or New Zealand.[5]

Motivated by these tendencies towards more flexible wage setting regimes at the industry level, this paper examines two related questions. Firstly, how do various unionization structures that differ with respect to wage centralization affect firms’ incentives for implementing labor productivity enhancing technologies? And secondly, what are the conditions under which workers prefer wage setting to be completely centralized, and when do workers prefer more flexible wage setting regimes?

Most of the existing theoretical work on the relationship between unionization and innovative activity has focused on how a union’s bargaining power and its objectives affect firms’ investment for labor cost reduction. Following the seminal work by Grout (1984), the conventional wisdom has been that a firm’s incentives are decreasing with union bargaining power because of the union’s hold-up incentive to raise its wage demands after investments are sunk. As this reduces the firm’s expected return on investment, unionization will reduce investment incentives (see also Malcomson 1997). More recent work by Tauman and Weiss (1987) and Ulph and Ulph (1994, 2001) has qualified this underinvestment result by considering oligopolistic competition between firms in the final goods market (for a survey see Ulph and Ulph 1998).[6]

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[3] See Sachverständigenrat (1998, pp. 117-127) where “wage flexibility clauses” of recent industry-wide tariff agreements in Germany are summarized. One example is the 1997 collective wage agreement for the construction industry in eastern Germany, according to which companies may reduce the collectively agreed wage by up to 10 percent.

[4] See Büttner and Fitzenberger (1998) for wage dispersion under industry-wide wage setting in Germany.

[5] For a country-wise survey of recent trends towards more flexible wage setting system see, e.g., Katz (1993). For the Australian case see in particular Wailes and Lansbury (1999). The breakdown of centralized wage bargaining in Denmark and Sweden is documented in Iverson (1996). The Swedish case is also studied extensively in Hibbs and Locking (2000). For the period 1950-1992, a more conservative view is expressed in Wallerstein et al. (1997).

This literature has focused exclusively on firm-level unionization, i.e., one polar case where wages are set at the firm-level by independent unions. Hence, the relative performance of more centralized wage setting systems remains an open issue, even though the degree of wage centralization has been identified as a crucial feature of different unionization structures. Our focus is, therefore, on different unionization structures and how they affect firms' incentives to undertake labor productivity enhancing investments. Moreover, we also analyze workers' preferences for different unionization structures.

More precisely, we introduce a unionized oligopoly model, where firms decide about productivity enhancing investments in the first stage, labor unions determine wages in the second stage, and finally, firms compete in Cournot fashion on the product market. We compare three unionization structures with "decentralized," "coordinated," and "centralized" wage setting. Under the decentralized structure wages are determined at the firm-level without coordination among unions. In contrast, under centralization an industry-union sets one uniform wage tariff for all firms across the entire industry. Centralization at an intermediate level implies industry-wide coordination on the union's side, but at the same time it allows for adjustments at the firm-level. As we will show the (interfirm) wage differentials can be ordered according to the degree of centralization. Wage dispersion is completely compressed under centralized wage setting while it is largest under a decentralized wage structure. At the intermediate level of centralization the wage differential lies in between those polar cases.

Concerning firms' investment incentives, we show that a uniform wage rule acts as an insurance device that protects firms' investments against opportunistic wage demands. The intuition for this result can be gained by contrasting centralized wage setting with the intermediate case where firm-level unions coordinate in setting a differentiated wage profile. Suppose that initially two firms are in the industry and that both firms are symmetric. If now one firm increases its labor productivity, industry wage-bill maximization implies a differentiated wage profile, where the more efficient firm pays a higher wage than the less efficient firm. Consequently, an "equal pay for equal work policy" constrains the union's wage demand, as any wage increase is now also imposed on the less productive firm. As a result, an innovative firm can appropriate more of the rent when wage setting is centralized.

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[6] For example, Tauman and Weiss (1987) consider a duopoly where only one firm is unionized. As the unionized firm faces a higher wage level it also can have larger incentives to invest. In Ulph and Ulph (2001) union strength can increase a firm's innovative effort under efficient bargaining, if the union cares a lot about employment (and not so much about wages). With Cournot competition in the final good market an increase in the firm's productivity will then mainly cause the rival firm to cut back its output level which increases the unionized firm's profits, and hence, its innovation incentives.

In contrast, decentralized structures allow for firm-specific wage adjustments that give rise to differentiated wage-profiles which increase the union's scope for appropriating some of the rent from the firms' specific investments. As a consequence, we show that firms undertake more costly investments if wage-setting is completely centralized. Hence, labor productivity is higher under complete centralization than under more decentralized unionization structures.

Next we show that workers can be better off adopting a centralized unionization structure, as this increases firms' investment incentives which in turn can boost wage revenues. However, if technological progress results in very asymmetric outcomes where successful innovators obtain a large competitive advantage over their rivals, workers tend to prefer coordinated wage setting with wage flexibility at the firm-level.

We also compare investment incentives under unionized labor markets with a perfectly competitive labor market. A centralized unionization structure can either lead to stronger or weaker investment incentives than a perfectly competitive labor market, depending on workers' reservation wage. In contrast, if wages are flexible at the firm level, investment incentives are always lower compared to perfectly competitive labor markets. Finally, we discuss policy issues that accrue from recent trends towards more flexible tariff settlements, as provided by so-called "opting out clauses".

While our paper contributes to the theory of innovation in unionized oligopolies, the dynamic efficiency effects of non-discriminatory pricing rules for monopolistically supplied inputs on downstream firms' investment incentives have been analyzed, for example, in DeGraba (1990). However, as this literature focuses on the normative issue of monopolistic input supplier regulation, it neither deals with decentralized supply structures nor does it provide a positive analysis of the stability of different supply structures.

Finally, our work is related to arguments which have been put forward in the Swedish debate over "solidaristic" bargaining (see Rehn 1952) that have been recently formalized in Agell and Lommerud (1993) and Moene and Wallerstein (1997). According to this literature, nation-wide wage settlements that are associated with a high degree of wage equality drive out inefficient firms, expedite structural change, and thereby, foster growth. In contrast, our analysis focuses on the role of different unionization structures to overcome the hold-up problem associated with unionization in oligopolistic industries.

The rest of this paper is organized as follows. In Section 2 we introduce the model's structure and define different unionization structures. We solve the model for the static case where firms' productivity levels are given in Section 3. Section 4 solves for firms' investment incentives and analyzes workers' preferred unionization structure and compares our results to investment incentives with perfectly competitive labor markets. In Section

5 we discuss implications for labor market policy, and finally, Section 6 concludes.

2 The Model and Unionization Structures

Consider a homogeneous goods Cournot duopoly, where firms are indexed by $i = 1, 2$. Both firms operate under constant returns to scale, with labor being the only factor of production. To produce a unit of the final good, firm i requires $1/\alpha_i$ units of a single input of homogeneous labor, where α_i is firm i's input-output coefficient. Denoting wages at firm i by w_i, firm i's marginal cost is then given by $\alpha_i w_i$. Let q_i denote the quantity of the final good produced by firm i, and let x_i be its labor demand. Since firm i requires α_i units of labor per unit of output, we have $x_i = q_i \alpha_i$. We assume a linear inverse demand function of the standard form $p = A - q_1 - q_2$.

Initially, i.e., before any cost-reducing investment is undertaken, both firms have the same labor productivity, $\alpha_1 = \alpha_2$, which we normalize to unity. However, firm 1 has the opportunity to undertake a labor-saving investment project which decreases its labor requirement per unit of output by Δ, with $0 < \Delta < \alpha_1$.[7] We denote a labor-saving investment project by $I(\Delta)$, where I is the cost for increasing labor productivity from $1/\alpha_1$ to $1/(\alpha_1 - \Delta)$. We suppose that the investment increases labor productivity instantaneously and is perfectly protected against imitation. As I is the amount that has to be sunk in order to implement a productivity enhancing technology, it also measures how severe the hold-up problem is that firm 1 faces under unionization. If an investment project does not involve any specific investment, then I is zero and, accordingly, the hold-up problem vanishes. Conversely, as I becomes larger the hold-up problem becomes more severe, and labor market organization becomes a critical determinant of firms' investment incentives.

The opportunity cost of labor, given through the workers' outside option such as their alternative income, is denoted by w_0, with $0 < w_0 < A$. It is assumed that the union maximizes its members' wage bill relative to the opportunity cost of labor, and we adopt the right-to-manage assumption: The union(s) can set the wage while each firm retains the right to choose its employment level.[8]

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[7] Our assumption that only one firm has the opportunity to undertake cost-reducing investment follows Bester and Petrakis (1993). It is also consistent with the patent tournament model of Ulph and Ulph (1998) where only one firm ends up as the exclusive patent right holder.

[8] In contrast to the right-to-manage assumption efficient bargaining models assume that unions and firms bargain over both wages and firms' employment levels (Oswald and Turnbull 1985, Layard et al. 1991, and Booth 1995). While it is true that unions rarely set wages unilaterally nor do they only care about wages, these simplifying assumption allow us to extract unions' incentives to exercise self-restraints as in the form of the "equal pay for equal work" commitment.

We consider a three stage game with the following timing: In the first stage, firm 1 decides whether or not to undertake a given investment project, $I(\Delta)$, that reduces firm 1's input-output-ratio by Δ at a cost of I. In the second stage, wages are determined, where we distinguish the three unionization structures $\rho = D, C, U$ with the following properties:

1. *Decentralization* ($\rho = D$): There are two firm-level unions which set firm-level wages w_1 and w_2 for their firms on behalf of the respective firm's employees. The two unions choose their wage demands simultaneously and noncooperatively.
2. *Coordination* ($\rho = C$): An industry union coordinates the wage demands w_1 and w_2 so as to maximize the industry wage bill.
3. *Centralization* ($\rho = U$): There is one industry-wide union which sets a *uniform* industry wage w for both firms so as to maximize the industry wage bill.

Finally, in the third stage of the game the two firms compete in quantities, taking productivity levels and wage rates as given.

This timing of the game is intended to reflect the planning horizon usually associated with the respective decisions. Investment decisions are mostly long-run while wage contracts are usually negotiated for a much shorter time horizon, and product market quantities can usually be adjusted on an even shorter basis.

The three unionization structures differ with respect to the degree of centralization in the following way: The D-regime can be viewed as the most decentralized system of collective wage setting, where firm-level unions do not cooperate and set firm-specific wages depending on the relative efficiency of their employer. In contrast, the U-regime stands for the most centralized wage setting system, as labor supply is perfectly monopolized and the industry union determines one uniform wage for all firms in the industry.[9] The C-regime lies in between those polar cases. On the one hand labor supply is completely monopolized, as an industry union coordinates wage demands at the firm level. On the other hand firm-level wages are adjustable to the firms' relative competitiveness. Consequently, different wages are likely to prevail in this case.[10]

At this point two remarks are at hand: Firstly, our notion of centralization requires either an industry union or intense coordination among firm-level unions. Secondly, the different labor market regimes also differ in terms of (inter-firm) wage flexibility. While neither regime D nor C imposes any restriction on wage flexibility the uniform wage setting regime U completely depresses any wage differential between firms. Hence, we portray centralization as a multidimensional concept.

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[9] This regime embodies the famous union-slogan "Equal pay for equal work."

[10] The C-regime stands for recent trends in continental Europe, where monopoly unions bargain over industry wage profiles that allow for more flexibility at the firm-level and for opting-out clauses for less efficient firms that are otherwise bound to the tariff-agreement (for recent trends see also OECD 1997).

Before we compare the different regimes, let us introduce the following assumption in order to exclude corner solutions in which the non-innovating firm is driven out of the market.[11]

Assumption 1. *The investment projects under consideration lead to non-drastic productivity improvements in the sense that the union prefers the less efficient firm to remain active in the market even under the centralized wage-setting regime U; i.e.,*

$$w_0 < \overline{w}_0(\Delta) \equiv \frac{(1-3\Delta)A}{1-\Delta^2}, \tag{1}$$

which implies that we restrict attention to productivity increases $\Delta < 1/3$.

Assumption 1 ensures that all optimization problems in the second and third stage of the game stay globally concave. We maintain Assumption 1 throughout the rest of the paper.

3 The Static Case: Given Productivity Levels

Let us begin our analysis by solving for the subgame perfect equilibrium quantities and wages, taking firms' productivity levels as given. Firm 1's profit function is

$$\Pi_1 = (A - q_1 - q_2)q_1 - w_1(1-\Delta)q_1,$$

and firm 2's profits are given by

$$\Pi_2 = (A - q_1 - q_2)q_2 - w_2 q_2.$$

For given wages w_1 and w_2, the firms' subgame perfect strategies are

$$q_1(w_1, w_2, \Delta) = \frac{A - 2w_1(1-\Delta) + w_2}{3}, \tag{2}$$

$$q_2(w_1, w_2, \Delta) = \frac{A - 2w_2 + w_1(1-\Delta)}{3}. \tag{3}$$

Now turn to the wage-setting stage. Wage-bill maximization implies that the union's optimal wage setting strategy, w_i^ρ, regarding firm i is defined as

$$w_i^\rho = \arg\max_{w_i \geq 0} U_i^\rho(w_i, w_j^\rho) \text{ for } i = 1, 2,\ i \neq j,$$

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[11] Assumption 1 is derived in the Appendix. Similar restrictions are also employed in Bester and Petrakis (1993) and Ulph and Ulph (1994, 1998, 2001).

for regimes $\rho = U, C, D$ where $U_i^D = x_i(w_i - w_0)$, $U_i^C = \sum_{i=1}^2 x_i(w_i - w_0)$, and $U_i^U = \sum_{i=1}^2 x_i(w - w_0)$ for the respective regimes, where labor demands x_i are derived from equations (2) and (3). Lemma 1 and 2 summarize our results concerning equilibrium wages and quantities.

Lemma 1. *For the different unionization structures the equilibrium wages are as follows:*
(i) Decentralization (D): $w_1^D = \frac{5A+2w_0(5-4\Delta)}{15(1-\Delta)}$ *and* $w_2^D = \frac{5A+2w_0(5-\Delta)}{15}$.
(ii) Coordination (C): $w_1^C = \frac{A+w_0(1-\Delta)}{2(1-\Delta)}$ *and* $w_2^C = \frac{A+w_0}{2}$.
(iii) Centralization (U): $w^U = \frac{(2-\Delta)A+2w_0(1-\Delta+\Delta^2)}{4(1-\Delta+\Delta^2)}$ *for* $i = 1, 2$.

Substitution of the equilibrium wages into equations (2) and (3) gives the firms' equilibrium output levels.

Lemma 2. *Under the different unionization structures* $\rho = D, C, U$ *the equilibrium production quantities for firm 1 and 2 are as follows:*

$$\begin{aligned} q_1^D &= 2\left(5A - w_0(5-7\Delta)\right)/45 \text{ and } q_2^D = 2\left(5A - w_0(5+2\Delta)\right)/45, \\ q_1^C &= (A - w_0(1-2\Delta)/6 \text{ and } q_2^C = (A - w_0(1+\Delta)/6, \\ q_1^U &= q_1^C + \frac{A\Delta}{4(1-\Delta+\Delta^2)} \text{ and } q_2^U = q_2^C - \frac{A\Delta(1-\Delta)}{4(1-\Delta+\Delta^2)}. \end{aligned}$$

Using the results of Lemma 1 and comparing equilibrium wages and the inter-firm wage differential, $d_w^\rho \equiv w_1^\rho - w_2^\rho$, across the three different regimes, we obtain the following ordering:

Corollary 1. *For all* $\Delta > 0$*, the ordering of the wages* w_1 *and* w_2 *and the wage differential,* $d_w^\rho \equiv w_1^\rho - w_2^\rho$*, under the different unionization structures is as follows:*
(i) Firm 1's wages: $w_1^C > w^U > w_1^D$.
(ii) Firm 2's wages: $w^U > w_2^C > w_2^D$.
(iii) Wage differentials: $d_w^D > d_w^C > d_w^U (= 0)$.

Corollary 1 shows how wage-setting depends on the particular mode of unionization. Decentralized wage-setting leads to the lowest wage levels compared to more centralized structures. Under coordinated wage-setting without a uniformity rule ($\rho = C$) a positive wage-differential results where the efficient firm pays the highest wage. However, the wage-differential under regime C is lower than under system D. The ordering of the wage differentials mirrors our notion of wage-setting centralization as discussed above. Wage-setting under the completely decentralized regime D is most responsive to firms' characteristics, so that productivity differences between firms translate into the largest wage differentials. On the other side of the spectrum, centralized wage setting under regime U depresses any heterogeneity in the wage-setting process so that wage differentials vanish.[12]

The ordering of wage differentials under the unionization structures mirrors the empirical finding that wage dispersion is negatively correlated with wage centralization, which is documented in OECD (1997), Flanagan (1999), and Wallerstein (1999). Interestingly, even though the intermediate regime C and the decentralized regime D both allow for full flexibility at the firm-level, the wage profile is more compressed under regime C than under D. This is because under decentralized wage setting the high-cost firm's union is willing to accept a lower wage in order to restall its firm's competitiveness on the product market. In contrast, an industry union fully internalizes the negative "business stealing" externality of this policy. Hence, under a coordinated wage setting regime (C) the union's incentive to adjust firm 2's wage to a lower level in response to an increase in firm 1's productivity is much weaker.[13]

From Corollary 1, we can also gain further insights how the severity of the hold-up problem that firm 1 faces varies under the three unionization structures. Noting that $\Pi_i = q_i^2$ must hold in equilibrium and using equation (2), we can also write firm 1's profits as

$$\Pi_1 = \frac{1}{9}\left(A - w_1(1-2\Delta) - d_w\right)^2. \tag{4}$$

This expression of firm 1's profits allows us to identify two different hold-up effects. Firstly, firm 1's profits are being reduced as the wage level, w_1, increases, and secondly, profits decrease as the wage differential between the two firms widens. Hence, there are two kinds of hold-up:

1. *Wage-level hold-up:* An increase in firm 1's wage level - while holding the wage differential constant - unambiguously reduces the gains from innovation; $\partial\Pi_1/\partial w_1 < 0$.
2. *Wage-differentiation hold-up:* An increase in the wage differential - while holding the wage level constant - unambiguously reduces the gains from innovation; i.e. $\partial\Pi_1/\partial d_w < 0$.

While the first kind of hold-up has received some attention in the respective literature, the second way of rent extraction seems to be much less recognized. From Corollary 1 we see that the wage-level hold-up is largest under the C regime and lowest under the D regime. This ordering may suggest that decentralized wage-setting is the mode of labor market organization that is most conducive to innovation. However, as part (iii) of Corollary 1 reveals, decentralized wage-setting also involves the largest hold-up potential via wage-differentiation. This may counter the positive effects of lower wage levels on incentives to invest.

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[12] It should be noted that centralized wage agreements often establish wage floors where firms may decide to pay higher wages. This may be explained by efficiency wage considerations or other frictions in labor market contracting that are beyond the scope of this paper.

[13] From Lemma 1 it follows that $\partial w_2^D/\partial\Delta < \partial w_2^C/\partial\Delta$.

Comparison of regimes C and U shows that both the wage level and the wage differential are strictly lower under regime U than under C. Hence, the uniformity rule under centralized wage setting restricts the union's hold-up potential and, therefore, induces larger investment incentives. Comparison with the decentralized wage-setting regime, however, remains ambiguous so far. While under regime D the wage level is the lowest, it also involves the largest scope for hold-up by wage differentiation.

Before turning to firms' investment decisions, let us ask which unionization structure workers prefer in the short run, i.e. in the absence of innovation. Unsurprisingly, workers prefer an unconstrained monopoly union over both a constrained monopoly union (U) or a fragmented unionization structure (D) since under regime C the unconstrained wage bill maximum can be implemented. We can, therefore, state the following result:

Proposition 1. *In the short run (where firms' productivity levels are given), the wage bill is maximized under regime C if* $\Delta > 0$.

As will become clear in the next section, workers' preferences are likely to change when firms' investment incentives are taken into account.

4 The Dynamic Case: Productivity Improvements

4.1 Investment Incentives

Incentives to invest depend on how innovation affects firms' profits. Hence, we need to analyze how firm 1's profits change with a productivity enhancing investment under different modes of labor market organization.

The increase in firm 1's profit gives us the maximum expenditure on productivity enhancing investment that it is willing to undertake. Let us define $I^{\rho} \equiv \Pi_1^{\rho}(\Delta) - \Pi_1^{\rho}(0)$, with $\rho = D, C, U$, where $\Pi_1(\Delta)$ is firm 1's equilibrium profit if a given investment project $I(\Delta)$ is undertaken, and $\Pi_1(0)$ stands for firm 1's equilibrium profit if it does not carry out the investment project.[14,15] The following proposition states the main

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[14] In the following the argument "Δ" describes the investment case and the argument "0" stands for the no-investment case.

[15] Note that comparing only the marginal incentives to invest (i.e. comparing $\partial\Pi^{\rho}/\partial\Delta$ for $\rho = D, C, U$)

result regarding firm 1's investment incentives:

Proposition 2. *Innovation incentives are largest under unionization structure U and smallest under unionization structure C; i.e.* $I^U > I^D > I^C$.

Proof. See Appendix.

Before commenting on Proposition 2, let us shortly digress to the literature on patent tournaments under unionization in order to link our results more closely to the existing literature (most importantly, to Ulph and Ulph 1998). In a patent tournament firm i is granted a license for a new technology if firm j does not purchase it. In this case, the competitive threat faced by firm 1 is different, as firm 2 will have the competitive advantage should firm 1 decide not to purchase the patent. Hence, firm 1's reservation price for obtaining the patent, P^ρ, is given by the difference in profits between the efficient and the inefficient firm; i.e. $P^\rho \equiv \Pi_1^\rho(\Delta) - \Pi_1^\rho(-\Delta)$, where $\Pi_1^\rho(\Delta)$ stands for firm 1's equilibrium profits if it obtains the exclusive right to use the patented technology. Accordingly, $\Pi_1^\rho(-\Delta)$ is firm 1's profit if the rival firm 2 receives the patent. Comparison of the different regimes shows that the ordering obtained in Proposition 2 is preserved in a patent tournament.

Proposition 3. *The firms' reservation prices for the patented innovation are largest under unionization structure U and smallest under structure C; i.e.* $P^U > P^D > P^C$.

Proof. See Appendix.

Proposition (2) and (3) show that different unionization structures have different effects on investment incentives. Our ordering of unionization structures along the dimension of wage centralization shows that a completely centralized wage-setting system carries the largest investment incentives. Furthermore, the relationship between wage centralization and innovative activity is non-monotone. Investment incentives are lowest when centralization is intermediate; i.e. if an industry union can differentiate wage demands across firms. This means that while the wage-differentiation hold-up is less severe under intermediate centralization than under decentralization (as the wage structure is more compressed), the magnitude of the wage-level hold-up under intermediate centralization outweighs this. Hence, the hold-up is larger in total under intermediate centralization, so that intermediate centralization has the most negative effects on investment incentives among the three regimes.

The first finding has important implications for empirical work on the relationship between unionization and productivity or innovation.[16] While much of the existing work

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would be misleading since firm 1's reduced profit function is not concave in Δ.

[16] Starting with the seminal work of Brown and Medoff (1978) there is a large body of empirical

focuses on union coverage and union density as measures of unionization, our results indicate that wage centralization can also significantly affect firms' innovative behavior.

Our second finding, namely that investment incentives are non-monotone with respect to centralization, calls for a critical reassessment of recent trends towards more flexibility in industry-wide wage settlements. As those agreements often remain highly coordinated on the union's side our results indicate that flexibility can also adversely affect innovation incentives while the desired positive effects on employment may remain small or even negligible as long as labor supply remains monopolized. Before we elaborate on this issue in Section 5, let us first analyze which regime workers actually prefer.

4.2 Workers' Preferred Unionization Structure

Given that investment incentives are strongest under the least flexible wage setting regime (U), the question arises which unionization structure would arise endogenously if workers could decide which one to adopt. As demonstrated in the next proposition, while coordinated wage setting can also be optimal, dynamic considerations may lead workers to prefer a uniform wage setting regime.

Proposition 4. *In the long run, the wage-bill maximizing unionization structure depends on* $I(\Delta)$*, with* $\Delta > 0$*, as follows:*

(i) If $I(\Delta)$ *is undertaken under all regimes (*$I(\Delta) < I^C$*), then workers prefer regime C.*

(ii) For $I^C < I(\Delta) < I^U$ *there exists a threshold value* $\widetilde{\Delta}(w_0)$ *such that the wage bill is maximized under regime U if* $\Delta > \widetilde{\Delta}(w_0)$ *and under regime C if* $\Delta < \widetilde{\Delta}(w_0)$*. The threshold value* $\widetilde{\Delta}(w_0)$ *is increasing in* w_0*.*

(iii) If the investment project is not undertaken under any regime, i.e., $I^U < I(\Delta)$*, then workers are indifferent between regimes C and U.*

Proof. See Appendix.

Proposition 4 shows that workers may prefer a completely centralized unionization structure (U) in order to provide a credible commitment against opportunistic wage adjustments, thereby inducing investment that would not have occurred otherwise. If,

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literature studying the effects of unionization on productivity and innovation (see, e.g., Freeman and Medoff 1984, Connolly et al. 1986, Addison and Hirsch 1989, Hirsch 1991, Bronas and Deere 1993, Addison and Wagner 1994). For a recent survey see Menezes-Filho et al. (1998). All in all the empirical results are mixed; there is no unambiguous relation between union power (measured by union density or union coverage) and productivity enhancing activities.

however, the relevant investment projects lead to large asymmetries between firms, workers will prefer the same regime ex ante as ex post, namely coordinated wage setting (C). Hence, our model may also help to explain why trends may emerge away from highly centralized unionization structures towards more flexible wage setting regimes: As firms' innovative activities lead to "more asymmetric" outcomes, unions are more inclined to allow for firm-level adjustments in wage formation. While it seems to be a widely held belief that declining union density and increasing management or shareholder power are the driving forces behind the erosion of centralized systems, Proposition 4 identifies reasonable conditions under which unions themselves will support those tendencies.[17] In particular, when innovations become more drastic so that market outcomes become more asymmetric, unions are more likely to refrain from uniformity commitments.

4.3 Comparison with Perfectly Competitive Labor Markets

Since in policy debates over labor market reform it is often argued that policy makers should take a more active role in introducing more labor market flexibility, it is useful to relate our results to the benchmark case of perfectly competitive labor markets where unionization is completely suppressed. Comparing our three regimes to a perfectly competitive labor market (under a product market duopoly) yields the following result:

Proposition 5. *Investment incentives are strictly larger under a perfectly competitive labor market* ($\rho = *$) *than under coordinated* ($\rho = C$) *or decentralized wage-setting* ($\rho = D$)*. However, investment incentives are larger under centralized wage setting* ($\rho = U$) *than under perfectly competitive labor markets* ($\rho = *$) *if* $w_0 < A/4$*. For all* $A/4 < w_0 < A$ *there exists a threshold value* Δ^* *such that* $I^* > I^U$ *if* $\Delta < \Delta^*$ *and* $I^* < I^U$ *if* $\Delta > \Delta^*$*. Moreover,* Δ^* *is monotonically increasing in* w_0*.*

Proof. See Appendix.

Proposition 5 shows that unionization can in fact carry larger investments incentives than perfectly competitive labor markets. This, however, is only the case for completely centralized wage setting where the risk of a hold-up through wage differentiation is completely eliminated. As unionization leads to a wage rate above the competitive wage, firms face a more elastic demand for their products, which can induce higher investment activity under unionization. If, however, the reservation wage is sufficiently large, this effect vanishes and a perfectly competitive market is likely to exhibit larger investment incentives, as the wage level hold-up reduces firms' investment incentives under unionization. As Proposition 5 also states slightly more flexible wage-setting institutions result in strictly lower investment incentives compared to the benchmark case.

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[17] See also Katz (1993) who reports that unions have frequently supported moves towards decentralization. A related point has been made by Lindbeck and Snower (2001) who show that recent trends towards more flexible production techniques correspond with an increasing resistence against centralized bargaining structures.

5 Labor Market Policy Implications

What are the implications our model has for labor market policy? At the latest since Calmfors and Driffill (1988) the question of the optimal degree of wage-setting centralization has been most contentious and subject to a vigorous debate. The central questions are how the labor market organization affects unemployment on the one hand and productivity on the other, and relatedly, whether a change in labor market policy can induce more favorable outcomes. While quite a number of economists argue that labor market rigidities and centralized wage-setting institutions are at the root of the unemployment problem and also responsible for the poor economic performance of many European countries (see, e.g., Siebert 1997), others point at the positive dynamic efficiency effects as firms have stronger incentives to increase their labor productivity when labor markets are less flexible (see, e.g., Kleinknecht 1998). While the first line of reasoning is regularly put forward by economic experts such as the council of economic advisers in Germany (see, e.g., Sachverständigenrat 1998, 117-127), union representatives usually concur with the second argument and claim that wage differentiation opens the window for wage dumping (*Schmutzkonkurrenz*), which reduces firms' incentives to increase their labor productivity (see, e.g., Flassbeck and Scheremet 1995 or Soltwedel 1997). Similar arguments have also been put forward in the Swedish debate over "solidaristic" bargaining (see Rehn 1952).

As we have demonstrated in our model, there may be some truth in both lines of reasoning, depending on the severity of the hold-up problem, the nature of innovation, and other factors as workers' reservation wage. Therefore, and since policy makers usually care about both employment effects and investment/productivity, it is useful to summarize our results for policy purposes as follows:[18]

Remark 1. *Depending on* $I(\Delta)$ *we obtain the following results:*

(i) For $I^D < I(\Delta) < I^U$ *coordinated wage setting under a uniformity rule (U) provides the largest investment incentives but results in lower employment than regime D.*

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[18] Using the results of Lemma 2 it is easily established that employment (i.e., $q_1(1-\Delta)+q_2$) is largest under regime D. As Assumption 1 holds, this is also true if an investment project is not undertaken under D but under U.

(ii) Otherwise, decentralized wage setting maximizes employment while not affecting investment.

In light of Remark 1, an extension of antitrust rules to labor markets, as called for by some economists (see, e.g., Baird 2000 and Haucap et al. 2001), may not be unwarranted. A strict application of antitrust rules would mean that the formation of industry-wide unions and collective wage agreements were not allowed due to their monopolization effects. While such a prohibition may imply lower productivity, our model predicts that employment would increase. If, however, the creation of monopoly unions is allowed for some reason, another antitrust rule may come into force, namely non-discrimination rules. The requirement not to discriminate between firms would increase investment incentives without lowering employment in our model.

In summary, policy makers may face a trade-off between more employment and higher productivity in case (i) of Remark 1. Interestingly though, allowing for an industry union and wage flexibility at the firm-level is never optimal for policy makers who care about both employment and productivity. Hence, in the light of our model labor market policy may be well advised either to restrict union formation altogether or to impose non-discrimination rules on collective wage agreements. Based on these accounts, we are left with the uncomfortable finding that labor markets are nevertheless exempted from antitrust law.[19]

Even if the application of antitrust laws to labor markets is not a politically viable option, our model casts severe doubts on the merits that slightly more flexible wage institutions, which allow for differentiated wage profiles (e.g., through opting out clauses) may have in highly centralized labor markets. In the light of our model, introducing intermediate levels of centralization appear to be the worst policy option available, not only on an economy-wide basis as stated by Calmfors and Driffill (1988), but also on an industry-wide level.

6 Conclusion

As we have shown in this paper, firms' incentives to invest in productivity enhancing technology are non–monotone in the degree of wage-setting centralization at the industry level.[20] If coordinated wage-setting is combined with strict uniform wage rules investment incentives are largest, while coordinated wage setting alone performs worst in terms of innovative activity. Our results, therefore, suggest to distinguish coordinated wage regimes along the lines of wage flexibility. For this purpose, it should prove useful that the degree of centralization is monotone in the interfirm wage differential, which suggests that it should be used as an explanatory variable in a reduced form approach.

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[19] For the European Union and, e.g., Germany there is no dispute that the labor market is completely exempted from antitrust regulations (see, e.g., Rittner 1999). While in the United States the *Pennington* case has proved that antitrust laws can be imposed on agreements beween unions and employers, the overall picture is similar as in Europe (for an assessment of the US situation see, e.g., Sullivan and Grimes 2000, pp. 716-727).

While it is conventional wisdom that rigidities in European labor markets are the main cause for the high unemployment in Europe, we would also point to the commitment value that these rigidities provide, as they help to reduce the hold-up problem associated with unionism. Since the conventional arguments for labor market deregulation are based on a static framework without innovation, they fail to capture the commitment aspects associated with different forms of labor market organization. In contrast, our paper has analyzed the strategic incentives to innovate under different modes of labor market organization and we argued that "equal pay for equal work" rules may be beneficial as they can encourage innovation. In this case, policy makers face a trade-off between high employment and productivity when designing labor market regulations and labor market policy more generally.

While we do not wish to over-emphasize this point, we believe that understanding the institutional complementarities of labor market organization and innovation is crucial for discussing the effects of labor market deregulation. The costs and benefits of labor market regulation are likely to be less clear-cut than is sometimes argued (see, for example, Siebert, 1997). While decentralization leads to higher employment levels in our framework, it also reduces innovation incentives. In contrast, a highly inflexible and centralized regime carries the highest innovation systems, but leads to lower employment than a decentralized regime. An intermediate degree of centralization with only some (in)flexibility appears to be especially undesirable in the light of our analysis.

For our model, we have used the simplifying assumption that firms are initially symmetric. If, however, we assume instead that firms are already asymmetric when they decide about any investment, the natural question arises how wage-setting systems affect the evolution of oligopoly markets. While we have to leave a definite answer to further research, we conjecture that centralized wage-setting under a uniformity rule is likely to increase asymmetries between firms, while a decentralized system may give rise to offsetting effects. Other areas for further research may be to fully endogenize the choice of labor market institutions and to analyze investment incentives under different degrees of centralization *and* different bargaining patterns or union preferences.

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[20] The empirical literature is generally not conclusive on the relationship between various measures of labor market rigidity and economic growth. The OECD, for example, recently concluded: "While higher unionization and more co-ordinated bargaining lead to less earnings inequality, it is more difficult to find consistent and clear relationships between those key characterictics of collective bargaining systems and aggregate employment, unemployment, or economic growth" (OECD 1996, p. 2).

Appendix

Derivation of Condition (1) in Assumption 1.

We first derive condition (1), which is a sufficient condition that ensures that all firms produce strictly positive output levels. Then we show that Assumption 1 guarantees interior equilibrium outcomes such that the less efficient firm 2 has a strictly positive production quantity under all three unionization structures.

Assume that we face regime U, and, for the moment, also suppose that firm 2 is not active. Then, firm 1's optimal choice in the third stage is given by $q_1(w, \Delta) = [A - w(1-\Delta)]/2$. Accordingly, the union sets w to maximize $U = (1-\Delta)q_1(w - w_0)$ which yields the optimal wage $w(\Delta) = [A + w_0(1-\Delta)]/[2(1-\Delta)]$. This, however, cannot constitute an equilibrium outcome as long as firm 2's labor demand remains strictly positive. Firm 2's best response function in the third stage of the game is given by $q_2(q_1, w) = \max\{A - q_1 - w)/2, 0\}$, and by substituting $q_1(w, \Delta)$ and $w(\Delta)$ we obtain that $q_2(q_1, w) > 0$ if condition (1) holds. Hence, condition (1) is sufficient to exclude corner solutions under regime U where only the efficient firm stays in the market.

We next show that condition (1) guarantees interior solutions under all three unionization structures. Under the different structures, firm 2's equilibrium output levels (which are given in Lemma 2) are strictly positive for $w_0 < \overline{w}_0^D \equiv 5A/(5+2\Delta)$, $w_0 < \overline{w}_0^C \equiv A/(1+\Delta)$, and $w_0 < \overline{w}_0^U \equiv (2 + 5\Delta^2 - 5\Delta)A/[2(1+\Delta)(1-\Delta+\Delta^2)]$ for D, C and U, respectively. It is straightforward to check that $\overline{w}_0(\Delta) < \overline{w}_0^U < \overline{w}_0^C < \overline{w}_0^D$. As condition (1) is the most restrictive one, it ensures that firm 2 has strictly positive output levels under all unionization structures.

Proof of Proposition 2.

We can obtain firm 1's equilibrium profits directly from Lemma 2 as $\Pi_1 = q_1^2$ must hold in equilibrium. We have to compare $I^\rho = \Pi_1^\rho(\Delta) - \Pi_1^\rho(0)$ with $\rho = D, C, U$. We obtain

$$\begin{aligned}
I^D &= \left(280\Delta w_0(A - w_0) + 196\Delta^2 w_0^2\right)/2025, &(5)\\
I^C &= \Delta w_0(A - w_0(1-\Delta))/9, &(6)\\
I^U &= \left(\frac{(2 + 2\Delta^2 + \Delta)A - 2w_0(1-2\Delta)(1-\Delta+\Delta^2)}{12(1-\Delta+\Delta^2)}\right)^2 - \left(\frac{A - w_0}{6}\right)^2. &(7)
\end{aligned}$$

Let us first compare I^D and I^C. Using (5) and (6) yields that $I^D > I^C$ if and only if $w_0 < \widetilde{w}_0 \equiv 55A/(55 + 29\Delta)$, which is implied by Assumption (1) since $\widetilde{w}_0 - \overline{w}_0 =$

$8A\Delta\frac{4\Delta+17}{(55+29\Delta)(1-\Delta^2)} > 0$. Secondly, to compare I^U and I^D, let us define $a \equiv (A - w_0)/3$, $b \equiv \frac{2\Delta w_0}{3} + \frac{A\Delta}{2(1-\Delta+\Delta^2)}$ and $c \equiv 7\Delta w_0/15$. Then, we can rewrite equations (7) and (5) as $I^U = (\frac{8}{9}a + \frac{4}{9}b)\frac{9}{16}b$ and $I^D = (\frac{8}{9}a + \frac{4}{9}c)c$. Hence, for $I^U > I^D$ it is sufficient to show that $9b/16 > c$, which reduces to $w_0 < 135A/\left[64(1 - \Delta + \Delta^2)\right]$, which is implied by Assumption 1. Hence, $I^U > I^D$ and, therefore, $I^U > I^D > I^C$.

Proof of Proposition 3.

We have to compare $P^\rho = \Pi_1^\rho(\Delta) - \Pi_1^\rho(-\Delta)$ for $\rho = D, C, U$ with "Δ" indicating that firm 1 holds the exclusive patent for the new technology and "$-\Delta$" indicating that firm 2 holds the exclusive patent for the new technology. Let us first compare P^D and P^C. We obtain $P^D = 4w_0\Delta(2(A - w_0) + w_0\Delta)/45$, and $P^C = w_0\Delta(2(A - w_0) + w_0\Delta)/12$, so that $P^D > P^C$ if $w_0 < \frac{2A}{2-\Delta}$ which holds by Assumption 1.

Now let us turn to the comparison of P^U and P^D. Define $a \equiv (A - w_0)/3$, $b \equiv 2\Delta w_0/3 + A\Delta/\left[2(1 - \Delta + \Delta^2)\right]$, $c \equiv 7\Delta w_0/15$, $d \equiv 2\Delta w_0/15$ and $e \equiv \Delta w_0/3 + A\Delta(1 - \Delta)/\left[2(1 - \Delta + \Delta^2)\right]$. We can write the investment incentives under regimes U and D as follows: $P^U = (2ab + b^2 + 2ae - e^2)/4$ and $P^D = 4(2ac + c^2 + 2ad - d^2)/9$. It follows that $P^U > P^D$ if and only if

$$a\left[2(b + e) - 32(c + d)/9\right] + b^2 - e^2 > 16(c^2 - d^2)/9.$$

For this condition to be satisfied, it is sufficient to show that the following two conditions are jointly fulfilled:

$$2(b + e) \;>\; \frac{32}{9}(c + d), \tag{8}$$

$$b^2 - e^2 \;>\; \frac{16}{9}(c^2 - d^2). \tag{9}$$

Given that $b + e = \Delta w_0 + \frac{A\Delta(2-\Delta)}{2(1-\Delta+\Delta^2)}$ and $c + d = 3\Delta w_0/5$, (8) holds for $w_0 < \frac{15A(2-\Delta)}{2(1-\Delta+\Delta^2)}$, which is implied by Assumption 1. Turning now to requirement (9) note that

$$\begin{aligned} b^2 - e^2 &= \frac{\Delta^2}{12}\left(4w_0^2 + 4Aw_0\frac{1+\Delta}{1-\Delta+\Delta^2} + \frac{3A^2\Delta(2-\Delta)}{(1-\Delta+\Delta^2)^2}\right) \quad \text{and} \\ c^2 - d^2 &= (\Delta w_0)^2/5. \end{aligned}$$

Hence, we know that (9) must be fulfilled if $\Delta^2 w_0\left[w_0 + A(1 + \Delta)/(1 - \Delta + \Delta^2)\right]/3 > 16(\Delta w_0)^2/45$, which reduces to $w_0 < \frac{5A(1+\Delta)}{2(1-\Delta+\Delta^2)}$, which again holds by Assumption 1. Hence, $P^U > P^D$ follows, and, therefore, $P^U > P^D > P^C$.

Proof of Proposition 4.

An investment project $I(\Delta)$ is undertaken under regime ρ ($\rho = D, C, U$) if and only $I \leq I^\rho$. Due to Proposition 1, we can restrict the analysis to the three cases stated in the proposition. Regarding cases (i) and (iii) an investment project is undertaken under every regime and under no regime, respectively. Consequently, it follows that the wage-bill maximizing regime is C in case (i) and C or U in case (iii). We can thus restrict attention to the remaining case (ii).

Using Lemma 1 and 2 we can write the industry wage bills under the unionization structures as

$$\begin{aligned}
U^D(\Delta) &= (100A(A-2w_0+w_0\Delta)+100w_0^2(1-\Delta)+106w_0^2\Delta^2)/675,\\
U^C(\Delta) &= (A(A-w_0(2-\Delta))+w_0^2(1-\Delta)+w_0^2\Delta^2)/6,\\
U^U(\Delta) &= \frac{(A(2-\Delta)-2w_0(1-\Delta+\Delta^2))^2}{24(1-\Delta+\Delta^2)}.
\end{aligned}$$

We first show that regime D is never optimal for workers. If a project $I(\Delta)$ is not undertaken under either D or C (i.e., $I(\Delta) > I^D$), then C must be the wage-bill maximizing regime. Secondly, if a project is undertaken under D (and, thereby, also under U), but not under C (i.e., $I(\Delta) > I^C$), comparison of U^U and U^D yields that $U^U(\Delta) > U^D(\Delta)$ if and only if

$$\frac{\phi_1(\Delta, w_0)}{120(1-\Delta+\Delta^2)} > 0 \text{ where}$$
$$\phi_1(\Delta, w_0) = 4w_0^2(5-2\Delta+3\Delta^2+2\Delta^3+\Delta^4)-4Aw_0(10-7\Delta+3\Delta^3+7\Delta^2)+5A^2(4(1-\Delta)+\Delta^2).$$

Calculating $\partial\phi_1(\Delta, w_0)/\partial w_0$, we obtain that this is negative if $w_0 < \frac{1}{2}\frac{A(3\Delta+10)}{5+3\Delta+\Delta^2}$, which holds by Assumption 1. Using again Assumption 1 we set $w_0 = \frac{(1-3\Delta)A}{1-\Delta^2}$ which we substitute into $\phi_1(\Delta, w_0)$. This gives the expression $(A\Delta)^2(133-172\Delta+222\Delta^2-44\Delta^3+5\Delta^4)/\left(1-\Delta^2\right)^2$, which is strictly positive for all $0 < \Delta < 1/3$. Hence, for case (ii) only C and U can be optimal.

Comparing now the respective wage bills gives that $U^U(\Delta) - U^C(0)$ is positive if

$$\frac{\Delta\phi_2(\Delta, w_0)}{24(1-\Delta+\Delta^2)} > 0, \text{ where} \tag{10}$$
$$\phi_2(\Delta, w_0) = 4Aw_0(1-\Delta+\Delta^2)-4w_0^2(1-2\Delta+2\Delta^2-\Delta^3)-3A^2\Delta.$$

As the denominator of (10) is strictly positive, the sign of $U^U(\Delta) - U^C(0)$ is given by the sign of $\phi_2(\Delta, w_0)$. As this expression is quadratic in w_0, we prove the existence of a unique threshold $\widetilde{\Delta}(w_0) > 0$ such that $\phi_2(\widetilde{\Delta}(w_0), w_0) = 0$ in an indirect way. Note that this also implies $\phi_2(\Delta, w_0) > 0$ for $\Delta > \widetilde{\Delta}$ and $\phi_2(\Delta, w_0) < 0$ for $\Delta < \widetilde{\Delta}$. Solving the quadratic form $\phi_2(\Delta, w_0) = 0$ we obtain two critical values

$$w_{0,1} = \frac{A}{2}\left(\frac{1-\Delta(1-\Delta)-\sqrt{(1-5\Delta+9\Delta^2-8\Delta^3+4\Delta^4)}}{1-2\Delta+\Delta^2(2-\Delta)}\right), \tag{11}$$
$$w_{0,2} = \frac{A}{2}\left(\frac{1-\Delta(1-\Delta)+\sqrt{(1-5\Delta+9\Delta^2-8\Delta^3+4\Delta^4)}}{1-2\Delta+\Delta^2(2-\Delta)}\right),$$

such that (10) holds if $w_0 < w_{0,1}$ or $w_0 > w_{0,2}$. Note, however, that $w_{0,2} > \overline{w}_0(\Delta)$ for all $\Delta \geq 0$. Hence, $w_0 > w_{0,2}$ can never hold. Now let us show that the term in brackets in (11) is monotonically increasing in Δ. Calculating its derivative reveals that the sign of the derivative is determined by the expression

$$\frac{1}{2}\frac{[1+\Delta-12\Delta^2+16\Delta^3-8\Delta^4]+2\Phi(1-\Delta+\Delta^2)}{(1-\Delta)\,[1-2\Delta+2\Delta^2-\Delta^3]\,\Phi} \tag{12}$$

with $\Phi = (1-2\Delta)\sqrt{1-\Delta+\Delta^2}$. We show that (12) is positive for all $0 \leq \Delta < 1/3$. Consider first the term in rectangular brackets of the nominator and define it by $\zeta(\Delta)$. Calculating the second derivative yields $\zeta''(\Delta) = -24(1-4\Delta(1-\Delta))$. As $\zeta''(\Delta)$ is maximized at $\Delta = 1/2$, it is straightforward to check that $\zeta''(\Delta) < 0$ for all $0 \leq \Delta < 1/3$, which implies that $\zeta(\Delta)$ is strictly concave over this interval. Evaluating $\zeta(\Delta)$ at the boundaries gives $\zeta(0) = 1$ and $\zeta(1/3) = 40/81$, so that $\zeta(\Delta)$ is strictly positive over $0 \leq \Delta < 1/3$. Next consider the second term in rectangular brackets of the denominator which we define by $\phi(\Delta)$. The first and second derivative of this term are $\phi'(\Delta) = -2+4\Delta-3\Delta^2$ and $\phi''(\Delta) = 2(2-3\Delta)$, respectively. It is immediate that $\phi''(\Delta)$ is strictly positive over $0 \leq \Delta \leq 1/3$. Evaluating $\phi'(\Delta)$ at the lower boundary $\phi'(0) = -2$ what implies that $\phi'(\Delta)$ is strictly decreasing over $0 \leq \Delta \leq 1/3$. Evaluating now $\phi(\Delta)$ at the upper boundary $\Delta = 1/3$ gives $\phi(1/3) = 14/27$ which is positive. Hence, $\phi(\Delta)$ is strictly positive over the interval $0 \leq \Delta < 1/3$. As the other terms of (12) are also positive we have shown that the threshold value $w_{0,1}$ is monotonically increasing in Δ. Moreover, for $\Delta = 0$ we obtain $w_{0,1} = 0$, and for $\Delta = 1/3$ we have $w_{0,1} = \frac{27}{28}A\left(\frac{7}{9}-\frac{1}{9}\sqrt{7}\right) > 0$. Combining the values for $w_{0,1}$ at the boundaries with the monotonicity of $w_{0,1}$ in Δ proves the existence of the unique threshold value $0 < \widetilde{\Delta} < 1/3$ for all $0 \leq w_0 \leq A$, and its monotonicity in w_0 as stated in Proposition 4.

Proof of Proposition 5.

We first derive the second-best investment incentives I^* with perfectly competitive labor markets. Then we prove the second part of the assertion which compares I^* and I^U. Then we prove the first part of the proposition.

If the labor market is perfectly competitive, then the prevailing wage rate is $w = w_0$. Hence, firm 1's equilibrium profits are $\Pi_1(w_0, \Delta) = (A - w_0(1-2\Delta))^2/9$. Accordingly, second-best investment incentives are defined by $I^* = \Pi_1(w_0, \Delta) - \Pi_1(w_0, 0)$ for which we obtain $I^* = 4w_0\Delta(A - w_0(1-\Delta))/9$. Comparing I^* and I^U we obtain

$$\begin{aligned} I^U - I^* &= \frac{\Delta\psi_1(\Delta, w_0)}{48\left(1-\Delta+\Delta^2\right)^2}, \text{ with} \qquad (13)\\ \psi_1(\Delta, w_0) &= A^2(4-\Delta+4\Delta^2) - 4Aw_0(5-11\Delta+15\Delta^2-10\Delta^3+4\Delta^4) \\ &\quad -8w_0^2(6\Delta-10\Delta^2+10\Delta^3-2-6\Delta^4+2\Delta^5). \end{aligned}$$

As the denominator is strictly positive the sign of $I^U - I^*$ is positive if

$$\psi_1(\Delta, w_0) > 0. \qquad (14)$$

Condition (14) is quadratic in w_0, which suggests an indirect way to prove the existence of a unique threshold $\Delta^*(w_0) > 0$ such that $\psi_1(\Delta^*(w_0), w_0) = 0$. Note that this also implies $\psi_1(\Delta, w_0) > 0$ for $\Delta > \Delta^*$ and $\psi_1(\Delta, w_0) < 0$ for $\Delta < \Delta^*$. Solving the quadratic form we obtain two critical values

$$\begin{aligned} w_{0,1} &= \frac{A}{8}\left(\frac{5-6\Delta+4\Delta^2-\sqrt{(16\Delta^4-32\Delta^3+56\Delta^2-40\Delta+9)}}{(1-\Delta)(1-\Delta+\Delta^2)}\right), \qquad (15)\\ w_{0,2} &= \frac{A}{8}\left(\frac{5-6\Delta+4\Delta^2+\sqrt{(16\Delta^4-32\Delta^3+56\Delta^2-40\Delta+9)}}{(1-\Delta)(1-\Delta+\Delta^2)}\right), \end{aligned}$$

such that (14) holds if $w_0 < w_{0,1}$ or $w_0 > w_{0,2}$. First note that $w_{0,2} > \overline{w}_0(\Delta)$ for all $\Delta \geq 0$, so that the second inequality never holds. We next show that the term in brackets in (15) is monotonically increasing in Δ. Calculating its derivative reveals that the sign of the derivative is determined by the expression

$$\left[2+48\Delta^5+20\Delta-112\Delta^4+148\Delta^3-99\Delta^2-16\Delta^6\right] + \Psi(4-12\Delta^3+4\Delta^4+19\Delta^2-12\Delta), \qquad (16)$$

with $\Psi = (1-2\Delta)\sqrt{(4\Delta^2-4\Delta+9)}$. We show that expression (16) is strictly positive for all $0 \leq \Delta < 1/3$. Consider the first term in rectangular brackets which we denote by ξ_1. This term is strictly concave over $0 \leq \Delta < 1/3$.[21] Evaluating ξ_1 at the boundaries gives to positive values, so that $\xi_1 > 0$ follows. As the remaining terms are also positive over $0 \leq \Delta < 1/3$ we can conclude that (16) is also positive, so that the threshold value $w_{0,1}$ is monotonically increasing in Δ. Moreover, for $\Delta = 0$ we obtain $w_{0,1} = A/4$ and for $\Delta = 1/3$ the value $w_{0,1} = 3A\left(31-\sqrt{73}\right)/112$. Combining the values for $w_{0,1}$ at the boundaries with the monotonicity of $w_{0,1}$ in Δ proves the existence of the unique threshold value $0 < \Delta^*(w_0) < 1/3$ and its monotonicity in w_0 for all $A/4 < w_0 < A$ as asserted in the Proposition.

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[21] To see this, differentiate ξ_1 successively with respect to Δ and use the restriction $0 \leq \Delta < 1/3$. It then follows that $\partial^2\xi_1/\partial\Delta^2 < 0$ must hold.

We finally show $I^* > I^D$ holds for all $0 < \Delta < 1/3$. First note that the difference $I^* - I^D$ is increasing in Δ, which follows form $\partial(I^* - I^D)/\partial\Delta = w_0(620(A - w_0) + 1408w_0\Delta)/2025 > 0$. For $\Delta = 0$ we get $I^* - I^D = 0$, so that $I^* > I^D$ holds for all $0 < \Delta < 1/3$. By Proposition 2 it also follows that $I^* > I^C$.

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