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IZA DP No. 13015

Unions, Tripartite Competition and Innovation

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ISSN: 2365-9793

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ABSTRACT

Unions, Tripartite Competition and Innovation*

We present theoretical and empirical evidence challenging results from early studies that found unions were detrimental to workplace innovation. Under our theoretical model, which extends the Cournot duopoly innovation model, local union wage bargaining is more conducive to innovation - particularly product innovation - than competitive pay setting. We test the theory with workplace data for Britain and Norway. Results are consistent with the theory: local union bargaining is positively associated with product innovations in both countries. In Norway, local union bargaining is also positively associated with process innovation.

JEL Classification: J28, J51, J81, L23, 031

Keywords: product innovation, process innovation, trade unions, collective bargaining

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* We thank the Norwegian Research Council for funding (grants No. 202647 and No. 295914). We thank participants at the 2015 Royal Economic Society Conference in Manchester and the 2016 European Association of Labour Economics in Ghent for comments on an earlier draft of this paper. Alex Bryson thanks the sponsors of the Workplace Employment Relations Survey 2011 (Department for Business Innovation and Skills, Acas, ESRC and NIESR) and the UK Data Archive for access to the WERS data.

1. INTRODUCTION

Innovation is an important source of productivity growth (Grossman and Helpman, 1991; Cummins and Violante, 2002; OECD, 2003; Griffith et al., 2004; Aghion and Howitt, 2007) which is why a vast literature examines factors that inhibit and promote innovation, including research and design (R&D) expenditure, patents and technological diffusion. One strand of this literature considers the role played by trade unions. Trade unions have a strong interest in firms' ability to innovate because innovation can affect labour demand - either positively via product innovation, or negatively where capital investments substitute for labour - and it offers opportunities for rent extraction. In their review of the literature Menezes-Filho and Van Reenen (2003) - henceforth MFVR - suggest the emerging evidence points to unions reducing R&D expenditure in the United States but not in Western Europe. However, they argue evidence on links between unionisation and other aspects of innovation is less clear cut and that "there is...a need to expand the samples of countries under study that are still very Anglo-Saxon biased" (p. 329). This remains the case today. We therefore extend the investigation of the union-innovation relationship beyond the Anglo-Saxon world to Norway, a country characterised by centralised, coordinated collective bargaining combining sectoral and local agreements. We make explicit comparisons with one of the Anglo-Saxon countries, Britain, which is far less unionised and where those unions that do exist do so at plant or organization level. This is valuable in its own right since the union-innovation link may have changed since the earlier empirical investigations.

Our contribution to the literature is three-fold. First, we build on the theoretical insights from Haucap and Wey (2004) to predict conditions under which product and process innovation emerge when three firms are in competition (tripartite competition). We show how these predictions differ from those under the Cournot duopoly model of Haucap and Wey. In doing so, we exploit insights from Bloom et al. (2013) regarding business stealing effects of R&D. Throughout, we emphasise the distinction between product and process innovation (Lin and Saggi, 2002)[1], an important distinction given the recent theoretical contributions focusing on links between union structure and product innovation (Basak and Mukherjee, 2014), and the previous studies emphasizing the relationship between these different kinds of innovation and the intensity of competition (Bonanno and Haworth, 1998).

Second, we show that, under plausible assumptions, local union wage bargaining can be more conducive to innovation – particularly product innovation – than purely competitive wage setting. This is the case because union voice effects affect the cost of facilitating and implementing

[1] Although product innovation accounts for two-thirds of all R&D investment in the U.S. is devoted to product R&D the theoretical literature largely focused on process innovation until Lin and Saggi (2002).

innovations (Bryson et al., 2013) so that under local union pay setting these costs can be lower than under the other regimes.

Third, we test this proposition empirically with comparable workplace data for Britain and Norway, thus answering MFVR's call for more empirical analysis from beyond the Anglo-Saxon world. We argue that whereas Britain and Norway obviously differ in terms of unionisation, they are similar with respect to technology use and competitiveness (WEF, 2013) and previously they are not too different when it comes to innovations and R&D levels (OECD, 2007: Figure 5.9). However, our focus is not to draw inference between countries, but rather use within country correlations between unionisation and innovation to show the value of local level unionisation - regardless of differences in union institutions, and regardless of differences in levels of innovation across countries.

The remainder of the paper is structured as follows. Section 2 reviews the previous theoretical and empirical literatures linking innovation to unionisation. Section 3 presents a theoretical model of union wage structures, product and process innovation. Section 4 describes our data and key measures. Section 5 outlines the empirical strategy. Section 6 reports our results and Section 7 concludes.

2. PREVIOUS LITERATURE

2.1 THEORY

The literature portrays trade unions as agents distorting relative prices via wage bargaining and "featherbedding" thus increasing firms' labour costs, reducing their profitability and investment activity (Oswald, 1985; Hirsch, 1992; Johnsen, 1990). This view has received some empirical support (Menezes-Filho, 1997), but it is also contested since it ignores the potential value of union 'voice'. Through voice mechanisms unions can reduce worker grievances, lower worker turnover - and the associated labour costs - thus raising tenure and firms' incentives to invest in human capital, all of which can increase productivity (Freeman and Medoff, 1984). Another literature has emerged noting that the structure of collective bargaining differs between countries and is important for productivity and innovation (Agell and Lommerud, 1993; Moene and Wallerstein, 1997; Haucap and Wey, 2004; Braun, 2011; Barth et al., 2015).

The early literature on unions and innovation focused on the "hold-up" problem (Grout, 1984; Malcomson, 1997) whereby unions seek to capitalise on firm sunk investments such as R&D to negotiate higher wages. This, in turn, may result in shareholder underinvestment if bargaining is not efficient.[2] Any underinvestment effect of unions, however, could be offset under conditions of oligopolistic competition where the strength of unions, coupled with the market structure, provide stronger incentives for innovation than under a competitive model (Ulph and Ulph, 1994, 1998, 2001).

While the wage level hold-up problem has been known for a long time, Haucap and Wey (2004) identified a new source of hold-up problem, namely wage differentiation hold-up: as the wage differential between firms increases, the profit of the innovating firm decreases. Their model delivers a unique ranking of the pay setting regimes when it comes to process investment incentives. They consider the incentives for process innovation under four distinct wage setting regimes: 1) the competitive case, 2) local bargaining, 3) central union setting with different local wages (coordinated case), and 4) central union setting with one wage across the sector. They show centralised union setting with one wage provides the highest incentives while coordinated but differentiated wage setting by a single union provides the lowest incentive. Local bargaining is a middle solution. Under their model the competitive case might perform better than the centralised case with one wage if the reservation wage is sufficiently high, but if the innovation is large enough then the centralised single-wage setting regime also beats the competitive case when it comes to process investment incentives.

In Haucap and Wey's (2004) model the payoff from innovation is larger for a highly productive firm under centralised wage setting than under local wage bargaining. This provides incentives both for process innovation and, as other studies have shown (Moene and Wallerstein, 1997; Barth et al., 2015), for job creation and employment. By contrast, firm level bargaining allows less productive firms to stay in the market and reduces average productivity. By incorporating collective bargaining into the heterogeneous firm productivity model of Melitz and Ottaviano (2008), Braun (2011) shows that sectoral bargaining is also associated with lower prices on average and less product variety than firm-level bargaining. If product variety is interpreted as the consequence of product innovation, this study then contrasts with Haucap and Wey in that local bargaining induces more innovation than collective bargaining.[3] We depart from the rest of the literature in our theoretical model by showing that if firms influence product demand directly via innovations then local union wage bargaining under certain assumptions can provide higher incentives for innovation than competitive wage setting.

[2] An optimal solution may still be achieved if bargaining is efficient, that is to say, if bargaining occurs over investments in addition to wages.

[3] Product variation might imply product differentiation in quality (vertical product differentiation) or differentiation in the number of products (horizontal differentiation). Empirically Khandelwal (2010) has identified substantial heterogeneity in product markets' scope for quality differentiation.

2.2 EMPIRICAL EVIDENCE

MFVR (2003) reviewed 31 studies on the impact of unionism on different innovation measures. Results are mixed. European studies diverge from their U.S. counterparts, and the sign of the raw correlations between unionism and innovation depends on the innovation measure (R&D intensity, the output of R&D and technology diffusion). For example, in the UK technological diffusion is unrelated to unionism conditioning on other factors (MFVR, 2003: 315, 326-327), although the raw correlations are positive. R&D intensity is negatively related to unionisation in the U.S., but unrelated in Germany and the UK. The authors speculate that the differences may arise from U.S. unions' focus on wages (2003:328), whereas European unions may give greater consideration to the employment consequences of their bargaining.

The recent empirical literature on the relationship between innovation and unionism is rather scarce and results are mixed. In their meta-analysis Doucouliagos and Laroche (2013) draw inferences from 28 studies using different union measures, innovation measures and empirical strategies. Their main results indicate that unions and innovations are negatively related, that this negative relationship is stronger in labour markets with weak regulation, but that this relationship is weakening over time. For Germany Addison et al. (2013) finds unionism does not retard innovation, and that sectoral collective bargaining might even be pro-innovative. In a similar vein, Vernon and Rogers (2013) provide empirical support for the notion that union strength in industrial unionism promotes productivity growth. For the UK, which is characterised by fragmented local bargaining and very little sectoral bargaining, Bryson et al. (2013) find that organizational changes akin to process innovations are associated with increased job-related anxiety and lower job satisfaction, but that the negative effects of organizational change on employee job-related anxiety are ameliorated when employees work in a unionised workplace and are involved in the introduction of the changes. This latter finding indicates that the implementation costs under local union pay setting can be lower than under the other regimes. Union effects on innovations in managerial practices (Human Resource Management) also appear to be positive. In their study for Britain Bryson, Forth and Kirby (2005) identify a positive association between HRM practices and labour productivity which is confined to union workplaces, but no HRM effect on financial performance. This is consistent with unions sharing rents generated by the improvements in labour productivity due to HRM practices. Of course, as Nickell (2001) notes, whatever a union can do to productivity (and, by extension, innovation) will be limited by market competition and market conditions and, as Freeman and Medoff (1984) noted three decades ago, by their relationship with management at the workplace.

3. THEORETICAL MOTIVATION

We take Haucap and Wey's (2004) model as a starting point but depart from it in three important ways. First, we focus on the presence of mixed pay setting schemes within a sector, a scenario that is common in the UK and Norway, even within narrowly defined industries (see Figures A1 and A2 for Norway and the UK respectively). Second, we introduce product innovation into the model and, thirdly, we extend it to cover tripartite competition.[4] Thus our model incorporates a productivity shifter associated with labour and heterogeneous implementation costs.

The model set-up is as follows: consider a homogeneous Cournot duopoly with three firms, i=1,2,3 operating under constant returns to scale, with labour as the sole production factor. Production quantity of firm i, q_i, is related to firm i's labour demand, l_i, by $l_i=\alpha_i q_i$ (this implies that a firm needs α_i to produce 1 unit of output, with marginal costs $\alpha_i w_i$, where w expresses the wage). In accordance with Haucap and Wey (2004), we assume a standard linear inverse product demand function $p=A-q_1-q_2 - q_3$ for $q_1+q_2+q_3 \leq A$.

Since α_i expresses a labour productivity shifter, we can shed light on the consequences of this by letting α_i vary between different kinds of wage setting or firms. Thus, we assume that $\alpha_i=\alpha_{LU}<1$ in the local union wage setting case but keep $\alpha_i=\alpha_C=1$ under competitive wage setting. When α deviates from 1, this naturally affects quantum and profits, and thus in the end the willingness to pay for innovations. The key point of α is that fewer workers are needed to produce one unit of the final good when workers are more productive.

These three firms engage in innovation races: each firm has the same chance to find the innovations (equal to one third). We consider two kinds of innovation: i) process innovation, which reduces a firm's labour requirement per unit of output by Δ ($\Delta>0$), and ii) product innovation, which increases the demand for a firm's product by Φ ($\Phi>0$). A firm might succeed in the patent race with two innovations, or none. The costs of implementing these innovations are sunk when implemented. The values of Δ, Φ and the costs associated with implementing the investments, $I(\Delta, \Phi)$, are known before firms start in the patent race. Higher values of I imply a larger hold-up problem.

Workers' outside options, w_0, provide the opportunity cost of labour. Union(s) maximise(s) their members' wage bill relative to their workers' outside options. We assume a right-to-manage approach: unions maximise wages, while firms chose the employment level.

[4] If one compares pure wage regimes the introduction of product innovation does not alter the basic theoretical findings of Haucap and Wey (2004).

Like Haucap and Wey we consider a three-stage game. In the first stage, the firms decide whether or not to participate in the patent race. In the second stage, wages are determined. In the third stage, the firms compete on quantities, taking production levels and wage rates as given. The model is solved via backward induction, i.e., we establish profit and wages first taking the patent race and productivity levels as given, and then address the participation decision.

3.1 Wage setting

We compare two different kinds of wage setting:

i) Competitive wage setting (denoted by C): In the competitive case, a firm pays a wage equal to workers' outside options, $w_0=w_1=w_2=w_3$.

ii) Local wage setting (denoted by LU): Each union maximises the local wage bill in excess of outside options, i.e., if $U_i(w_i)$ expresses the utility of the union in firm i, they maximise: $\max_{wi}U(w_i)=\max_{wi} l_i (w_i-w_0)=\max_{wi} q_i (w_i-w_0)$.

3.2 Equilibrium quantities and wages

Since the three firms participate in two innovation races, two different sets of outcomes might occur: i) one firm might succeed with both innovations and the other loses both, or ii) they might end up winning one innovation race each. For simplicity we focus on i). We let firm 1) be the winner of the innovation race.

The firms' profits can be written:

1) $$\Pi_1=(A - q_1 - q_2 - q_3+ \Phi A)q_1 - \alpha_i (1- \Delta)w_1 q_1,$$

$$\Pi_2=(A - q_1 - q_2 - q_3)q_2 - \alpha_i w_2 q_2,$$

$$\Pi_3=(A - q_1 - q_2 - q_3)q_3 - \alpha_i w_3 q_3,$$

Firms choses q_i to maximise profits while taking w_i and the competitor's production (q_j) as given, i.e., $\partial\Pi_i/\partial q_i=0$. Thus, two sets of equation emerge depending on whether the union firm is a winner or a looser of the innovation race.

A) Union firm as an innovation winner (firm 1):

2) $$q_1=[(1+3\Phi)A + w_2 + w_3 - 3\alpha_{LU}(1-\Delta)w_1)]/4,$$

$$q_2=[(1-\Phi)A + \alpha_{LU}(1-\Delta)w_1 + w_3 - 3w_2)]/4,$$

$$q_3=[(1-\Phi)A + \alpha_{LU}(1-\Delta)w_1 + w_2 - 3w_3)]/4.$$

B) Union firm as an innovation looser (then as firm 2):

3) $$q_1=[(1+3\Phi)A + \alpha_{LU}\, w_2 + w_3 - 3(1-\Delta)w_1)]/4,$$

$$q_2=[(1-\Phi)A + (1-\Delta)w_1 + w_3 - 3\, \alpha_{LU}\, w_2)]/4,$$

$$q_3=[(1-\Phi)A + (1-\Delta)w_1 + \alpha_{LU}\, w_2 - 3w_3)]/4.$$

Note that the ws in Equations 2) and 3) for those operating under competitive wage setting equal workers' outside options ($=w_0$).

Equations 2) and 3) show that the firm succeeding in the patent race can "poach" some of the product demand from its competitor directly, while firm 1's productivity enhancements influence firm 2's production levels negatively since, relatively speaking, it will have to pay higher wages. In competitive firms product and process innovation act symmetrically on production levels, but for the local bargaining firm the presence of union voice effects make product innovations more important for production than process innovation. Note also that the production levels and profits are closely related, since due to the first order conditions, firm i's profits expressed by Equations 1) and 2) can be rewritten: $\Pi_i= q_i^2$.

Given the two wage setting schemes of Section 3.1, we can then derive the following two sets of expressions for wages:

A) Union firm as innovation winner (firm 1):

4) $$w_1=[(1+3\Phi)A + (3\alpha_{LU}\, (1-\Delta)^2 + 2)w_0]/[6\alpha_{LU}\, (1- \Delta)],\ w_2= w_0,\ w_3= w_0\ .$$

B) Union firm as innovation looser (firm 2):

5) $$w_1= w_0,\ w_2=[(1-3\Phi)A + (3\alpha_{LU} -\Delta + 2)w_0]/[6\alpha_{LU}],\ w_3= w_0\ .$$

Equations 4) and 5) imply the following ranking of wages: $w_0 =w^{C}_{j}<w^{LU}_{j}(\text{looser})<w^{LU}_{j}(\text{winner})$, j=1,2,3. However, while Haucap and Wey identify two sources underlying the inefficiencies of local unions, the wage-level hold-up problem and the wage differentiation hold-up problem, higher labour productivity following union voice mitigates these. This is seen by considering the following equation for the local union winner:

6) $$\Pi_1 =q_1^2=[(1+3\Phi)A\ - (\alpha_{LU}\, w_1 - w_2) - (\alpha_{LU}\, w_1 - w_3) - \alpha_{LU}\, (1-3\Delta)w_1)]^2/16,$$

The three last terms in the brackets express the two hold-up problems, and we see that as labour productivity increases (ie, α becomes smaller), these three terms become less important. It remains the case, nevertheless, that higher wage levels for the innovation firm while holding the wage differential constant yield lower profits, and higher wage differentials for the innovation firm while holding the wage level constant yields lower profits.

Finally, we can express the firms' production levels as a function of the competitive wage, i.e.,

A) Union firm as innovation winner (firm 1):

7) $$q_1=[(1+3\Phi)A + (2 - 3\alpha_{LU}(1-\Delta)^2)w_0]/8,$$

$$q_2=[(7-3\Phi)A + (10 - 3\alpha_{LU}(1-\Delta)^2)w_0]/24,$$

$$q_3=[(7-3\Phi)A + (10 - 3\alpha_{LU}(1-\Delta)^2)w_0]/24.$$

B) Union firm as innovation looser (then as firm 2):

8) $$q_1=[(7+17\Phi)A – (10 - 3\alpha_{LU} - 17 \Delta)\, w_0]/24,$$

$$q_2=[(1-\Phi)A + (10 - 3\alpha_{LU} - 17 \Delta)\, w_0)]/8,$$

$$q_3=[(7-7\Phi)A + (10 - 3\alpha_{LU} + 7 \Delta)\, w_0]/24.$$

3.3 Innovation incentives

Haucap and Wey (2004) established that when only labour productivity enhancing innovations were possible, Δ would have to be strictly less than 1/3 (or $w_0 <(1- 3\Delta)A/(1- \Delta)^2$). This assumption was necessary to assert that the non-innovating firm was not driven out of the market (to avoid corner solutions). With competitive or local union set wages, this is less of a problem (the local union sets wages conditional on survival). For comparison reasons, we just limit Δ to be strictly less than 1/3. We focus attention on jointly moderate innovations, i.e., we also limit Φ to be strictly less than 1/3.

While we let Φ and Δ vary, we do not allow the employer to invest differentially in Φ and Δ, although we acknowledge that it might be easier to influence product demand considerably (by refining existing products or introducing new ones) compared to improving labour productivity dramatically. Furthermore, as seen by Equations 2) and 3) the presence of union voice effects makes product innovation more profitable than process innovation for the union firm.

The implementation costs, $I(\Delta, \Phi, \gamma_i)$, depend on pay-setting scheme (expressed by the subscript i), where lower values for γ_i imply lower implementation costs. For simplicity, in the competitive case we set $\gamma_c =1$. In line with the findings from the literature review (e.g., Bryson et al., 2013), we assume that $\gamma_{LU} <1$. Each player (firm) is equally likely as the winner, thus you win or lose with probability of one third. However, the union firm will be the looser twice. The expected profit from participating in the innovation race can thus be expressed:

9) Union firm: $(1/3)\ \Pi_1(\Phi,\Delta)+ (2/3)\Pi_2(0,0) - (1/3)[\ I(\Phi,\Delta, \gamma_{LU})]$.

Competitive firm, union firm looser: $(1/3)\ \Pi_1(\Phi,\Delta)+ (2/3)\Pi_2(0,0) - (1/3)[\ I(\Phi,\Delta, \gamma_c)]$.

Competitive firm, union firm winner: $(2/3)\ \Pi_1(\Phi,\Delta)+ (1/3)\ \Pi_3(0,0)] - (2/3)[\ I(\Phi,\Delta, \gamma_c)]$.

This expected profit from participating in the innovation race will have to exceed the profit of abstaining:

10) Union (A): $(1/3)[\ \Pi_i(\Phi,\Delta) - I(\Phi,\Delta, \gamma_{LU})]+ (2/3)\Pi_j(0,0)> \Pi_j(0,0)$,

Competitive(B): $(1/3)[\ \Pi_i(\Phi,\Delta) - I(\Phi,\Delta, \gamma_c)]+ (2/3)\Pi_j(0,0)> \Pi_j(0,0)$,

Competitive(C): $(2/3)[\ \Pi_i(\Phi,\Delta) - I(\Phi,\Delta, \gamma_c)]+ (1/3)\Pi_j(0,0)> \Pi_j(0,0)$,

(by not participating, a firm achieves the same profits as by losing the race). In other words, the profit gain from these innovations will have to cover the costs associated with implementing the innovations:

11) $$\Pi_i(\Phi,\Delta) - \Pi_j(0,0)- I(\Phi,\Delta, \gamma_i)>0.$$

Let us assume that this constraint is satisfied, i.e., the gain from these innovations by assumption exceeds the costs associated with participating in the innovation race. Since $\Pi_i= q_i^2$ for i=1,2,3 we can decompose the operating profit differentials for the firms depending on being innovation winner(W) or loser(L): $\Gamma = \Pi^W_i - \Pi^L_i = q^{W}_i{}^2 - q^{L}_i{}^2 = (q^W_i + q^L_j)(q^W_i - q^L_j)$, where Γ denotes the profit differential. More explicitly, we find:

12)Union: $\Gamma^U=(1/(8^2)[(4\ \Phi A+\Delta(1+3\ \alpha_{LU})\ w_0\ ]\ [(2+2\ \Phi)A+(4-6\alpha_{LU}-\Delta+3\alpha_{LU}\Delta)\ w_0\ ]$,

Comp: $\Gamma^{CB}= (1/(3^2 8^2)[(14+14\Phi)A-(20-17\Delta-3\alpha_{LU}\Delta)w_0\ ]\ [(20\Phi A+(6\alpha_{LU}+17\Delta-3\alpha_{LU}\Delta)w_0]$,

Comp: $\Gamma^{CC}= (1/(3^2 8^2)[(14+10\Phi)A-(20-10\Delta-6\alpha_{LU}\Delta)w_0\ ]\ [24\Phi A+24\Delta w_0]$.

Can we rank the pay schemes with respect to the Γs? Yes, but the ranking depends on the size of α_{LU}. On one hand, if no voice-effect exists, i.e., $\alpha_{LU}=1$, then $\Gamma^U< \Gamma^{CB}$ and $\Gamma^U < \Gamma^{CC}$. On the other hand, if $\alpha_{LU}=0$, then $\Gamma^U> \Gamma^{CB}$ and $\Gamma^U > \Gamma^{CC}$ (see appendix for proof). So as the productivity effect of the local union increases, the profits to the union firm innovating rise. Together with the implementation costs, these profit differentials express the willingness to pay for innovations. Thus, if no union voice-productivity effect exists and the implementation costs do not differ between competitive and union firms, then competitive firms have a higher willingness to pay for innovations than union firms. Under our assumptions, we obtain the opposite result. Which effect dominates is an empirical question. However, if the empirical analysis reveals that innovations occur more frequently among union firms, then this will be a strong indication of higher labour productivity or lower implementation costs among union firms than competitive firms.

4. EMPIRICAL STRATEGY

In our deterministic theoretical model all firms (they are only 3) satisfying Equation 12) enter the innovation race and succeed with a probability of one third. In reality, unobserved heterogeneity could influence Equation 12) in several ways:

14) $$p\Pi_1(\Phi,\Delta) - (1\text{-}p)\ \Pi_2(0,0) - pI(\Phi,\Delta,\gamma_i) + u_f \quad > \quad 0.$$

The innovation success probability (p), the degree of innovation (Φ,Δ), the implementation costs $I(\Phi,\Delta,\gamma_i)$ and other unobserved factors (expressed by an normally distributed error term u_f) could vary across firms, thus influencing the share of innovating firms in the economy. Thus, when we model the relationship between wage setting regime and innovations it is natural to apply the Probit regression framework to model the innovation probability of workplace f:

15) $$\Pr(\text{innovation}_f) = \beta \text{Bargaining}_f + X_f'\lambda + u_f,$$

where u_f is normally distributed, X is a control vector and Bargaining (=1) is a dummy taking the value of 1 if wage bargaining occurs (0 otherwise), and innovation (=1) expresses dummies taking the value of 1 if innovation occurs.

We estimate a series of Probit regressions modelling the probability of innovation. Then we estimate a series of bivariate SUR Probit regressions, modelling the probability of introducing new production technology and new or significantly improved products simultaneously while accounting for potential unobserved factors correlated with the incidence of both types of innovation.

We weight each observation in the regression by the inverse of the workplace's sampling probability (adjusted for non-response). This makes our empirical results representative at the national level for the population of workplaces with 5 or more employees (Britain)/10 employees (Norway). The models are identical for both countries, except for adding controls for Norway on skills through controls for average workforce educational attainment and age.

Our results capture simple conditional correlations. We ignore potential biases associated with simultaneity problems such as those arising from workplace unobservable features which are linked to both innovation activity and unionisation, and biases that might arise due to worker and workplace selection into trade union agreements.

5. DATA

Our data are the British Workplace Employment Relations Survey 2011 (WERS 2011) and the Norwegian Workplace Employment Relations Survey 2012 (NWERS 2012) supplemented by Norwegian register data. Although WERS (NWERS) covers workplaces with at least 5(10) employees in all sectors of the British (Norwegian) economy, we confine our analyses to the private sector. Information in WERS was acquired through face-to-face interviews which were conducted with the manager at the workplace responsible for employment relations. The response rate in 2011 was 46%. Information in NWERS was acquired through computer-assisted telephone interviews which were conducted with the daily manager at the workplace or the manager responsible for employment relations. The response rate was 54%, but since the main reason for non-response was respondents not being reached by Statistics Norway (36 percentage points) and not by respondents refusing to participate, selection issues are unlikely to be a problem.[5] WERS is documented in van Wanrooy et al. (2013), while NWERS is documented in Holmøy (2013).

Innovation measures

Our innovation measures for Britain are based on managerial responses to the following question: "Over the past two years has management here introduced any of the changes listed on this card? PROBE: Which others? UNTIL 'None'.:

1) Introduction of performance related pay
2) Introduction or upgrading of new technology (including computers)
3) Changes in working time arrangements
4) Changes in the organisation of work
5) Changes in work techniques or procedures
6) Introduction of initiatives to involve employees
7) Introduction of technologically new or significantly improved product or service
8) NONE None of these"

Our measure of labour-productivity enhancing process innovation is based on new production technology (a dummy taking the value of 1), which is defined directly from code 2). For product innovation we create a dummy for new or significantly improved products or services based on code 7).

[5] In NWERS only 12.7 percent of the issued sample refused to participate. In WERS detectable response biases were corrected using sampling weights.

The Norwegian innovation measures are very similar questions to the British measures. The measure for new or considerably improved products is based on two questions: "Over the last two years has the management introduced a new product?" and "Over the last two years has the management introduced considerable improvements of an already existing product?" Product innovation is then measured as a dummy taking the value of 1 if the manager response is yes to one of these questions, otherwise 0. Process innovation is based on the question: "Are the products or services provided by the workplace based on a different technology today compared to that of two years ago?" Process innovation is then measured as a dummy taking the value of 1 if the manager response is yes to this question, otherwise 0.

Finally, for both Britain and Norway, to acknowledge that our respondents might have misinterpreted the occurrence of product versus process innovation, we construct an innovation dummy taking the value of 1 if there is product or process innovation, zero otherwise.

Unionisation

In both countries, our measure of union coverage is the presence at the workplace of one or more unions recognised by the employer for bargaining over pay and conditions of employment, whether the bargaining occurs at the workplace, organization or sectoral-level (1=union coverage, 0=not covered). These data are derived from the management questionnaire in WERS and in NWERS.

We also construct two measures expressing the level of wage bargaining. The first is a dummy taking the value of 1 if local wage bargaining occurs at the workplace (irrespective of whether the workplace is also subject to sectoral or national level bargaining), 0 otherwise. This measure is constructed for Britain and Norway. Secondly, and for Norway only, for those workplaces involved in union bargaining which strictly cover more than one employer (e.g., at sectoral level or national level) and is *not* supplemented by additional local bargaining, we construct a dummy taking the value of 1, 0 otherwise.[6]

Finally, we also construct a simple measure of workplace union density.

Control variables

The previous literature as discussed by MFVR indicates that innovation is related to workplace age structure, market power and skill structure. The recent literature also maintains that incentive pay is important for innovation (Ederer and Manso, 2013; Curran and Walsworth, 2014). We control for these characteristics in steps.

[6] As becomes apparent in our descriptive results, we omit this case in Britain because it is very rare.

Our basic control vector comprises a dummy for newly started business (less than two years in Norway and less than five years in Britain), a dummy for weak competition, and 14 industry dummies (roughly 1-digit SIC industry codes, but slightly more detailed). This vector captures variations in workers' outside options and workplaces' entry decisions.

The full control vector then adds controls for the number of employees at the workplace (four dummy variables), product market conditions (a dummy expressing exporting workplaces, two dummies for increased or reduced product demand, a dummy for location in the capital city), workforce skills (the largest non-managerial occupational group (1-digit dummy) and for Norway, average workforce years of educational qualification and age), and incentive pay systems (one dummy in the case of Britain and two - for non-managerial and managerial employees - in the case of Norway). Market demand conditions are important for firms' innovation activities since they affect the potential returns to innovation investments. Achieving increased demand is one of the reasons why firms conduct product innovation in the theoretical model.

6. RESULTS

Table 1 presents descriptive information on the incidence of our key union variables in Britain and Norway. We show workplace-weighted and employee-weighted estimates. The first row indicates that union agreements are six times more common among workplaces in Norway (70% against 12%). This difference is driven primarily by differences in the incidence of multi-employer agreements: multi-employer agreements are virtually non-existent in British workplaces (1% of workplaces and <1% of employees) whereas they cover almost two-thirds (63%) of workplaces and 71% of employees in Norway.[7] Local agreements in the absence of multi-employer agreement are actually a little more common in Britain than they are in Norway.

In both countries, union agreements are more common in larger workplaces so the percentage of workers covered is higher than the percentage of workplaces. In Norway three-quarters of employees (77%) are covered by a union agreement compared to just under one-third (32%) in Britain. Nearly four times as many employees are employed in a local-agreement only workplace in Britain compared with Norway (24% against 7%). The percentage of employees in union membership (union density) is four times greater in Norway - 50% against 13% for Britain. This is driven in part by the lower incidence of collective bargaining in Britain but also by lower density where there is an agreement.

[7] The low incidence of multi-employer agreements means that for all practical purposes multi-employer agreements are ignorable in Britain. Thus, when we turn to the regression analyses, for Britain we only focus on a dummy for trade union agreements.

The surveys therefore confirm that the two countries conform to the characterizations of them in the literature: Britain has low unionisation rates and fragmented collective bargaining - akin to the U.S. whereas Norway has very high levels of unionisation, which are based on centralized multi-employer bargaining arrangements typical of the Scandinavian case.

[INSERT TABLE 1]

Table 2 shows the incidence of our innovation measures related to process and product innovation - and their relationship with unionisation.[8] Norwegian workplaces report a greater incidence of innovation overall than British workplaces (66% vs 57%). However, Britain has more process innovation than Norway but less product innovation. The rate of product innovation is almost twice as high in Norway as it is in Britain (60% against 33%), while technological process innovation is one-and-a-half times more common in Britain than Norway (48% against 30%).[9]

[INSERT TABLE 2]

These differences in product and process innovation are not accounted for by differences in the underlying industrial structures in the two countries.[10]

Table 2 also reveals that, in Britain, workplaces are more likely to engage in product innovation when unionised (44% relative to 32% if non-union). The union/non-union difference is negligible in Norway (56% against 57%) when comparing those employed under multi-employer sectoral bargaining only, but as in Britain workplaces are more likely to engage in product innovation with local union involvement (65%). In Britain union workplaces are more likely to engage in process innovation than non-union workplaces (53% v 48%). The picture is different in Norway: the union/non-union differentials are less pronounced. Based on these simple unconditional descriptive statistics it appears union status matters more for product and process innovation in Britain than it does in Norway. But, of course, these unconditional correlations may be very misleading. For instance, the incidence of unionisation and innovation are likely to be linked to workplace size.

Next, we turn to the results from the multivariate regressions. In Table 3 we estimate simple Probit-regressions to see how union bargaining arrangements relate to innovation, whether

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[8] All remaining analyses are workplace-weighted.

[9] Both the British and Norwegian product innovation figures are higher than the OECD-figures. While the text in the questionnaires that yield this information is similar, WERS and NWERS sample workplaces, while even smaller firms are sampled in the studies that yield the OECD-statistics. It is therefore likely that the lower OECD figures reflect, at least in part, small firms. Furthermore, NWERS provides a stratified sample taking into account time of entry, and the innovation activities might differ across the lifecycle of a workplace (or firm).

[10] To investigate the role played by industrial structure we produced counterfactuals for the incidence of innovation for each country by weighting their data using the industry composition taken from the other country. In a sense we are making Norway observationally equivalent to Britain based on its industrial structure, and vice versa. It was apparent that differences in industrial structure - at least at this two-digit level - account for only a relatively small part of the observed differences in innovation rates across the two countries. These analyses are available on request.

it be product or process innovation. In Norway innovation is positively associated with local trade union agreements, increasing the probability of innovation by around 10-14 percentage points compared with observationally equivalent non-unionised workplaces. In Britain we find no significant correlation between innovations and bargaining.

[INSERT TABLE 3]

Table 3 also indicates that the innovation rate among Norwegian workplaces differs with local versus centralised bargaining: regardless of model specification, innovation rates are higher in the presence of local bargaining.

Table 4 distinguishes between product and process innovation. The SUR estimates confirm there are strong positive correlations in the unobservables influencing process and product innovation. The first four columns report two models for Britain, the second four report two models for Norway.

[INSERT TABLE 4]

Once again we see the striking relationship between local union wage bargaining and innovation in Norway. For Norway *both* product or process innovation are 10 percentage points more likely to occur under local union bargaining than in the competitive case.[11] In Britain, local union bargaining is also strongly positively associated innovation, but only in the case of product innovation, inducing a 12 percentage-point higher innovation rate. Although this cannot be derived from our simple model, differential implementation costs for product and process innovations combined the fact that union voice effects make product innovations more profitable than process innovation (see Section 3.3), could make unionization associated with product innovation in both countries, but process innovation only in Norway.

7. CONCLUSION AND DISCUSSION

To our knowledge, this is the first workplace comparative analysis of the links between union bargaining and innovation. We compare union links to innovation in Britain and Norway, two very different countries in terms of union arrangements. Britain is akin to the U.S. with low levels of unionisation and, where union bargaining exists, it takes the form of local union agreements. In Norway, on the other hand, we find multi-employer agreements dominate, but a majority of the workplaces also face local bargaining. The distinction we make between product and process innovations proves informative. Indeed, failure to disaggregate between types of innovation would have produced misleading results. Local bargaining induces product innovation, increasingly so if

[11] As anticipated, market conditions matter for innovation, and then particularly increased product demand, which is significantly associated with increased innovation.

the local union causes higher worker productivity. Similarly, our efforts to distinguish between aspects of unionisation within country prove informative since we find results differ somewhat according to whether the union agreement is at local or multi-employer level. That said, there are stark differences in innovation rates and the links between innovation and union status of workplaces across our two countries, which seem to relate to the broad characterisations of the two union systems in the literature.

We find Norwegian workplaces were much more likely to undertake product innovation than British workplaces four years after the onset of the Great Recession, whereas process innovation was more prevalent in Britain than Norway. However, when it comes to the relationship between unions and innovations, we find that in both countries workplaces engaged in local union bargaining were 10-12 percentage points more likely to innovate on their products than workplaces that set wages in the absence of unions. In Norway, process innovations were 10 percentage points more likely to occur under local union bargaining than in the competitive case. Thus, local union bargaining appears conducive to innovations in both countries, particularly product innovation. This is as expected, as indicated by the theoretical model, that the voice-effect makes workers in local-union workplaces more productive than workers in other workplaces.

These empirical findings challenge the existing theories, which predict local union bargaining is detrimental to innovation. However, most of the existing studies were conducted some time ago. It is apparent from recent empirical studies that union effects on innovation indicate unions can be conducive to innovation. The positive association between unionisation and innovation is also consistent with our theoretical model in which we show that if firms influence product demand directly via innovations then local union wage bargaining under certain assumptions can provide higher incentives for innovation than competitive wage setting. Our model also predicts that hold up problems diminish with increasing productivity. The empirical literature on unions and productivity suggests that relative productivity in the union sector has risen over time. Early studies indicating negative union impacts no longer hold. For example, Blanchflower and Bryson (2009) show that the negative association between unionisation and productivity observed in the 1980s had disappeared by the 1990s. It is plausible that this change in the relative productivity of the union sector partly accounts for our empirical findings. We conclude that on both theoretical and empirical grounds, early studies suggesting unions are detrimental to innovation offer a misleading picture of union effects today.

Appendix

[INSERT TABLE A1]

The ranking of innovation incentives caused by running operating profits

No voice (α_{LU}=1):

Union: $\Gamma^{U}=(1/(24^{2})\ [(6+6\Phi)A+(6-6\Delta)w_0\ ]\ [(12\Phi A+12\Delta w_0\ ]$,

Comp: $\Gamma^{CB}=\ (1/(24^{2})[(14+14\Phi)A-(20-20\Delta)w_0\ ]\ [(20\Phi A+(6+14\Delta)w_0]$,

Comp: $\Gamma^{CC}=\ (1/(24^{2})[(14+10\Phi)A-(20-16\Delta)w_0\ ]\ [24\Phi A+24\Delta w_0]$.

Let us define the first and last terms in brackets for A and B, respectively. Then we see that $A^{U}<A^{CB}$ and $A^{U}<A^{CB}$ and $B^{U}<B^{CB}$ and $B^{U}<B^{CB}$. Thus $\Gamma^{U} < \Gamma^{CB}$ and $\Gamma^{U} < \Gamma^{CC}$, so competitive firms have the highest incentives for innovation when it comes to running operating profits compared to union firms when no productivity voice effect is present.

Maximum voice (α_{LU}=0):

Union: $\Gamma^{U}=(1/(24^{2})\ [(6+6\Phi)A+(12-3\Delta)w_0\ ]\ [(12\Phi A+3\Delta w_0\ ]$,

Comp: $\Gamma^{CB}=\ (1/(24^{2})[(14+14\Phi)A-(20-17\Delta)w_0\ ]\ [(20\Phi A+17\Delta w_0]$,

Comp: $\Gamma^{CC}=\ (1/(24^{2})[(14+10\Phi)A-(20-10\Delta)w_0\ ]\ [24\Phi A+24\Delta w_0]$.

Let us define as above the first and last terms in brackets for A and B, respectively. If $A<5\ w_0$, then we see that $A^{U}>A^{CB}$ and $A^{U}>A^{CB}$ and $B^{U}>B^{CB}$ and $B^{U}>B^{CB}$. Thus $\Gamma^{U} > \Gamma^{CB}$ and $\Gamma^{U} > \Gamma^{CC}$, so competitive firms have the lowest incentives for innovation when it comes to running operating profits compared to union firms. If $A>5w_0$, then this twist around.

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Table 1 Unionisation and collective bargaining

	BRITAIN		NORWAY	
Trade union agreement (TUA)	Workplaces	Workers	Workplaces	Workers
Any TUA	0.118	0.309	0.702	0.771
Multi-employer TUA with local	0.001	0.006	0.326	0.473
Multi-employer TUA without local	0.012	0.048	0.304	0.233
Local TUA only	0.102	0.236	0.072	0.065
Union density				
Union and non-union sectors	0.041	0.126	0.396	0.495
Any TUA	0.258	0.376	0.461	0.555
Multi-employer TUA with local	0.320	0.669	0.557	0.624
Multi-employer TUA without local	0.250	0.361	0.379	0.442
Local TUA only	0. 260	0.369	0.370	0.459

Note: Private sector workplaces only. Source: Workplace and Employment Relations Survey 2011 (Britain) and Norwegian Workplace and Employment Relations Survey 2012. The columns headed by workers and workplaces express whether the figures are representative for the population of workers or the population of workplaces, respectively.

Table 2 Unionisation and innovation

	BRITAIN			NORWAY			
	All	Not TUA	TUA	All	Not TUA	TUA-Local	TUA- Multi-employer only
Innovation measures							
Innovation	0.571	0.562	0.645	0.657	0.627	0.708	0.621
New product (P)	0.336	0.319	0.466	0.606	0.576	0.649	0.562
New prod. techno.(T)	0.483	0.477	0.548	0.310	0.277	0.354	0.273
New P AND new T	0.250	0.235	0.369	0.258	0.255	0.295	0.211

Note: Private sector workplaces only. TUA= trade union agreement. Source: Workplace and Employment Relations Survey 2011 (Britain) and Norwegian Workplace and Employment Relations Survey 2012. Each observation is weighted by the inverse of the sampling probability of the workplace adjusted for no-response. Thus the table reports figures representative across the distribution of workplaces.

Table 3 Overall incentives for innovation and union involvement

	Britain			Norway		
	1	2	3	4	5	6
TUA_local	0.217	0.143	0.109	0.261*	0.365**	0.417**
	(0.164)	(0.171)	(0.162)	(0.126)	(0.131)	(0.140)
	[0.085]	[0.052]	[0.037]	[0.096]	[0.127]	[0.135]
TUA_Multi-employer only				0.007	0.102	0.163
				(0.137)	(0.145)	(0.158)
				[0.003]	[0.036]	[0.053]
Controls						
Basic	Yes	Yes	Yes	Yes	Yes	Yes
Size, Market, Skills, Pay			Yes			Yes
Test						
TUA-local-TUA_Multi				0.254*	0.263*	0.254x
Prediction						
Predicted no TUA case	0.562	0.565	0.567	0.610	0.584	0.578
N	1831	1831	1831	1096	1095	1092

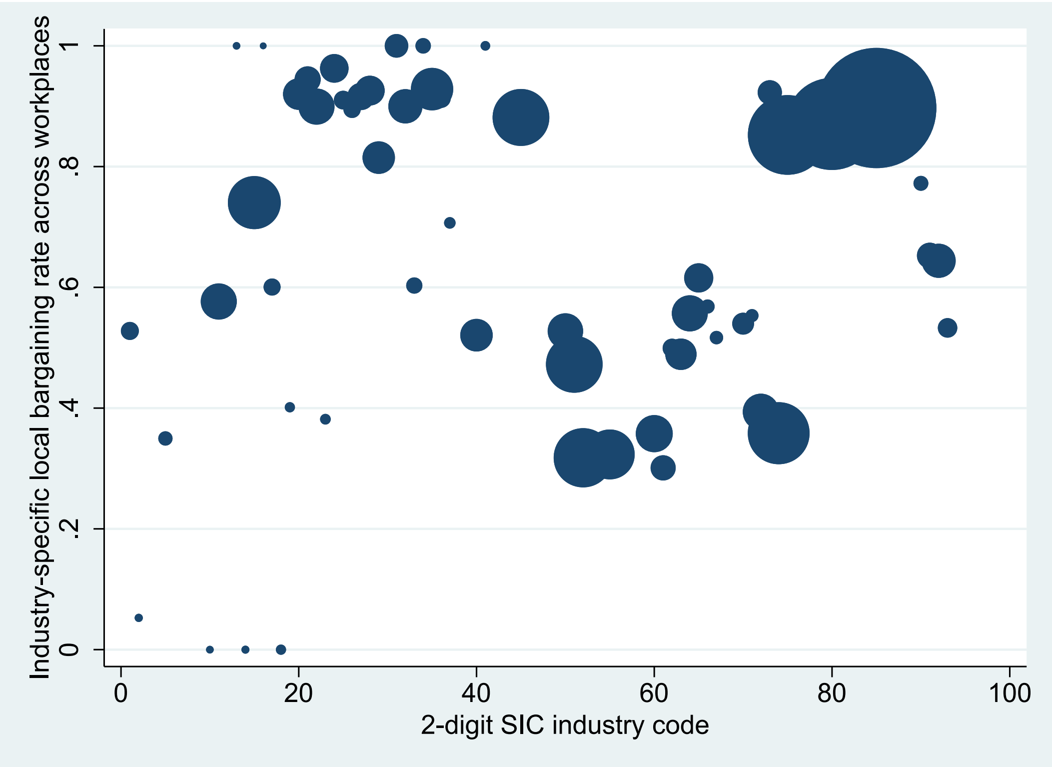
Note: Method: Probit. Dependent variable: dummy for innovation. Private sector workplaces only. Source: Workplace and Employment Relations Survey 2011 (Britain) and Norwegian Workplace and Employment Relations Survey 2012. Each observation is weighted by the inverse of the sampling probability of the workplace adjusted for no-response. Control vectors: *Basic*: dummies for newly started business, weak competition, easy to recruit employees, and 14 industry dummies; *Size, Market, Skills, Pay*: size (4 categories), dummies for increased or reduced demand, exporter, located in the capital, main occupation dummies, average workforce years of educational qualification and age (Norway only), performance pay for managers/workplace. Robust standard errors are reported in parentheses. Marginal effects are reported in squared brackets. x, * and ** denote 10, 5 and 1 percent level of significance, respectively.

Table 4 Do unions influence product or process innovation equally?

	Britain				Norway			
	1		2		3		4	
	New prod.	New tech.	New prod.	New tech.	New prod.	New tech.	New prod.	New tech.
TUA_local	0.350*	0.121	0.381*	0.095	0.273*	0.312*	0.302*	0.362*
	(0.176)	(0.163)	(0.165)	(0.160)	(0.131)	(0.135)	(0.139)	(0.145)
	[0.120]	[0.045]	[0.123]	[0.033]	[0.099]	[0.104]	[0.103]	[0.112]
TUA_Multi-e only					0.059	0.119	0.105	0.157
					(0.144)	(0.149)	(0.157)	(0.162)
					[0.022]	[0.040]	[0.036]	[0.049]
Controls								
Basic	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Size, Market, Skills, Pay			Yes	Yes			Yes	Yes
Cross-eq. correlation	0.547**		0.496**		0.544**		0.534**	
Test								
TUA-local-TUA_Multi					0.214 x	0.194	0.197	0.205
Prediction								
Predicted no TUA case	0.321	0.478	0.320	0.479	0.552	0.255	0.547	0.249
N	1831	1831	1831	1831	1095	1095	1092	1092

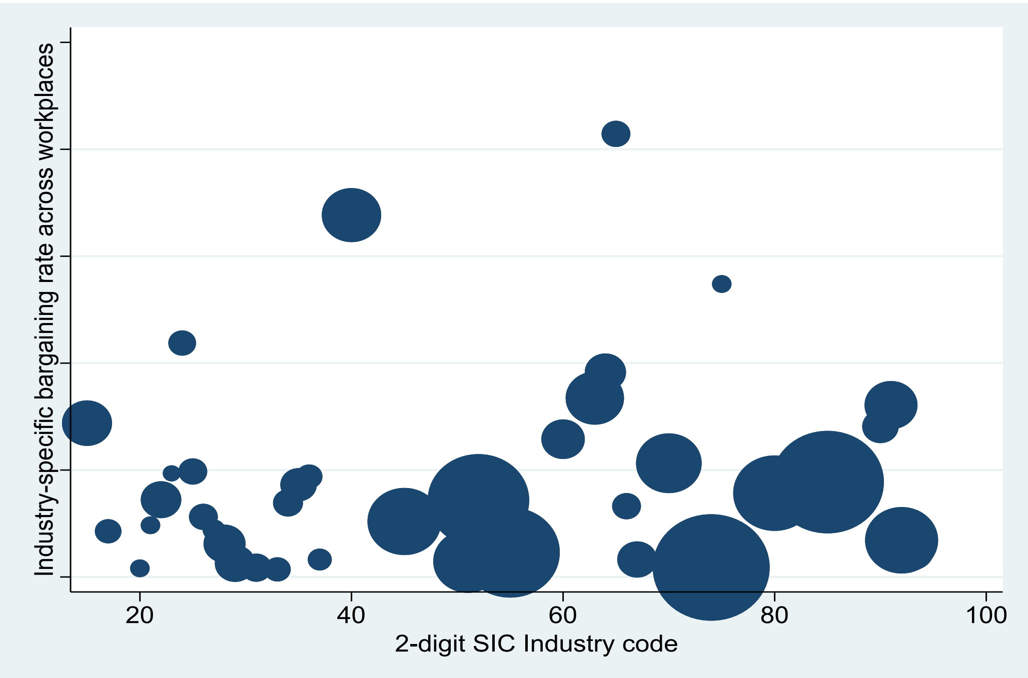
Note: Method: Bivariate SUR Probit-system. Dependent variable: dummies for product innovation and process innovation. Private sector workplaces only. Source: Workplace and Employment Relations Survey 2011 (UK) and Norwegian Workplace and Employment Relations Survey 2012. Each observation is weighted by the inverse of the sampling probability of the workplace adjusted for no-response. Control vectors: *Basic*: dummies for newly started business, weak competition, and 14 industry dummies; *Size, Market, Skills, Pay*: size (4 categories), dummies for increased or reduced demand, exporter, located in the capital, main occupation dummies, ceo/daily manager, average workforce years of educational qualification and age (Norway only), performance pay for managers/workplace. Robust standard errors are reported in parentheses. Marginal effects are reported in brackets. x, * and ** denote 10, 5 and 1 percent level of significance, respectively.

Figure A1 The local bargaining rate within Norwegian industries. 2012.



Note: Population: Graph based on the Norwegian NWERS2012-sample, which provide a nationally representative figures for the population of workplaces employing at least 10 employees. The size of the ‘blobs" define the number of workplaces within 2-digit industries.

Figure A2 The local bargaining rate within UK industries. 2011.



Note: Population: Graph based on the British WERS2011-sample, which provide a nationally representative figures for the population of workplaces employing at least 10 employees. The size of the ‘blobs" define the number of workplaces within 2-digit industries.

Appendix: Theoretical background and Calculations

We take Haucap and Wey's (2004) model as a starting point but depart from it in three important ways. First, we focus on the presence of mixed pay setting schemes within a sector, a scenario that is common in the UK and Norway, even within narrowly defined industries (see Figures A1 and A2 for Norway and the UK respectively). Second we introduce product innovation into the model and, thirdly, we extend it to cover tripartite competition.[12] Thus our model incorporates a productivity shifter associated with labour and heterogeneous implementation costs.

The model set-up is as follows: consider a homogeneous Cournot duopoly with three firms, i=1,2,3 operating under constant returns to scale, with labour as the sole production factor. Production quantity of firm i, q_i, is related to firm i's labour demand, l_i, by $l_i=\alpha_i q_i$ (this implies that a firm needs α_i to produce 1 unit of output, with marginal costs $\alpha_i w_i$, where w expresses the wage). In accordance with Haucap and Wey (2004), we assume a standard linear inverse product demand function $p=A-q_1-q_2-q_3$ for $q_1+q_2+q_3\leq A$.

Since α_i expresses a labour productivity shifter, we can shed light on the consequences of this by letting α_i vary between different kinds of wage setting or firms. Thus, we assume that $\alpha_i=\alpha_{LU}<1$ in the local union wage setting case but keep $\alpha_i=\alpha_C=1$ under competitive wage setting. When α deviates from 1, this naturally affects quantum and profits, and thus in the end the willingness to pay for innovations. The key point of α is that fewer workers are needed to produce one unit of the final good when workers are more productive.

These three firms engage in innovation races: each firm has the same chance to find the innovations (equal to one third). We consider two kinds of innovation: i) process innovation, which reduces a firm's labour requirement per unit of output by Δ ($\Delta>0$), and ii) product innovation, which increases the demand for a firm's product by Φ ($\Phi>0$). A firm might succeed in the patent race with two innovations, or none. The costs of implementing these innovations are sunk when implemented. The values of Δ, Φ and the costs associated with implementing the investments, $I(\Delta, \Phi)$, are known before firms start in the patent race. Higher values of I imply a larger hold-up problem.

Workers' outside options, w_0, provide the opportunity cost of labour. Union(s) maximise(s) their members' wage bill relative to their workers' outside options. We assume a right-to-manage approach: unions maximise wages, while firms chose the employment level.

Like Haucap and Wey we consider a three-stage game. In the first stage, the firms decide whether or not to participate in the patent race. In the second stage, wages are determined. In the third stage, the firms compete on quantities, taking production levels and wage rates as given. The model is solved via backward induction, i.e., we establish profit and wages first taking the patent race and productivity levels as given, and then address the participation decision.

[12] If one compares pure wage regimes the introduction of product innovation does not alter the basic theoretical findings of Haucap and Wey (2004).

Wage setting

We compare two different kinds of wage setting:

i) Competitive wage setting (denoted by C): In the competitive case, a firm pays a wage equal to workers' outside options, $w_0=w_1=w_2=w_3$.

ii) Local wage setting (denoted by LU): Each union maximises the local wage bill in excess of outside options, i.e., if $U_i(w_i)$ expresses the utility of the union in firm i, they maximise: $\max_{wi}U(w_i)=\max_{wi} l_i (w_i-w_0)=\max_{wi} q_i (w_i-w_0)$.

Equilibrium quantities and wages

Since the three firms participate in two innovation races, two different sets of outcomes might occur: i) one firm might succeed with both innovations and the other loses both, or ii) they might end up winning one innovation race each. For simplicity we focus on i). We let firm 1) be the winner of the innovation race.

The firms' profits can be written:

1) $$\Pi_1= (A - q_1 - q_2 - q_3+ \Phi A)q_1 - \alpha_i (1- \Delta)w_1 q_1,$$

$\Pi_2= (A - q_1 - q_2 - q_3)q_2 - \alpha_i w_2 q_2,$

$\Pi_3= (A - q_1 - q_2 - q_3)q_3 - \alpha_i w_3 q_3,$

Firms choses q_i to maximise profits while taking w_i and the competitor's production (q_j) as given, i.e., $\partial\Pi_i/\partial q_i=0$. Note that the FOC can be rearranged (the first equality):

2) $$q_1 = (A - q_1 - q_2 - q_3+ \Phi A) - \alpha_i (1- \Delta)w_1 = \Pi_1/ q_1,$$

$q_2 = (A - q_1 - q_2 - q_3) - \alpha_i w_2 = \Pi_2/q_2,$

$q_3 =(A - q_1 - q_2 - q_3) - \alpha_i w_3 = \Pi_3/q_3,$

i.e., $\Pi_i= (q_i)^2$.

You get two sets of equation depending on whether the union firm is a winner or a looser of the innovation race.

A) Union firm as innovation winner (firm 1), firms 2 and 3 competitive:

3) $$-2q_1 + (1+\Phi)A - q_2 - q_3 - \alpha_{LU}(1-\Delta)w_1 = 0,$$

$-2q_2 + A - q_1 - q_3 - w_2 = 0$,

$-2q_3 + A - q_1 - q_2 - w_3 = 0$.

In 3) we have utilised the assumption that since firm 1 is the union firm, then $\alpha_1 = \alpha_{LU}$, while $\alpha_2 = \alpha_3 = 1$.

Since $-2q_2 + A - q_1 - q_3 - w_2 = -2q_3 + A - q_1 - q_2 - w_3$, we easily see that X) $q_3 = q_2 + w_2 - w_3$.

Similarly, $-2q_1 + (1+\Phi)A - q_2 - q_3 - \alpha_{LU}(1-\Delta)w_1 = -2q_2 + A - q_1 - q_3 - w_2$. Thus,

XX) $q_2 = q_1 - \Phi A + \alpha_{LU}(1-\Delta)w_1 - w_2$.

Inserting X into $-2q_1 + (1+\Phi)A - q_2 - q_3 - \alpha_{LU}(1-\Delta)w_1 = 0$ then yields:

$2q_1 = (1+\Phi)A - (q_2 + q_2 + w_2 - w_3) - \alpha_{LU}(1-\Delta)w_1$, which if we inserts XX for q_2 yields:

$4q_1 = (1+3\Phi)A + w_2 + w_3) - 3\alpha_{LU}(1-\Delta)w_1$ or

$q_1 = [(1+3\Phi)A + w_2 + w_3 - 3\alpha_{LU}(1-\Delta)w_1]/4$

Inserting q_1) into XX) then yields:

$q_2 = [(1-\Phi)A + \alpha_{LU}(1-\Delta)w_1 + w_3 - 3w_2]/4$, and finally,

by inserting q_2) into X) one finds:

$q_3 = [(1-\Phi)A + \alpha_{LU}(1-\Delta)w_1 + w_2 - 3w_3]/4$.

Thus

4) $$q_1 = [(1+3\Phi)A + w_2 + w_3 - 3\alpha_{LU}(1-\Delta)w_1)]/4,$$

$q_2 = [(1-\Phi)A + \alpha_{LU}(1-\Delta)w_1 + w_3 - 3w_2)]/4$,

$q_3 = [(1-\Phi)A + \alpha_{LU}(1-\Delta)w_1 + w_2 - 3w_3)]/4$.

Since firm 1 is the local bargaining union firm, firms 2 and 3 set wages competitively, i.e. $w_2 = w_0$, $w_3 = w_0$.

For firm 1, we get:

$\max_{w1} (1-\Delta)q_1(w_1 - w_0) \rightarrow .0 = \partial\{(1-\Delta)[[(1+3\Phi)A + w_2 + w_3 - 3\alpha_{LU}(1-\Delta)w_1)]/4](w_1 - w_0)\}/\partial_{w1}$

$\rightarrow .[-3\,\alpha_{LU}(1\text{-}\Delta)^2(w_1\text{-}w_0)]+(1\text{-}\,\Delta)\ [(1+3\Phi)A + 2w_0\ \text{-}\ 3\alpha_{LU}(1\text{-}\Delta)w_1)]/4]=0$

$\rightarrow w_1=[(1+3\Phi)A + (3\alpha_{LU}\,(1\text{-}\Delta)^2 + 2)w_0]/[6\alpha_{LU}\,(1\text{-}\,\Delta)]$

Finally, we can express the firms' production levels as a function of the competitive wage, i.e., by plugging the expressions for wages into 4):

5) $q_1=[(1+3\Phi)A + w_0 + w_0\ \text{-}\ 3\alpha_{LU}(1\text{-}\Delta)\{(1+3\Phi)A + (3\alpha_{LU}\,(1\text{-}\Delta)^2 + 2)w_0]/[6\alpha_{LU}\,(1\text{-}\,\Delta)\})]/4$

$=[2(1+3\Phi)A - (1+3\Phi)A\ \text{-}\ 3\alpha_{LU}(1\text{-}\Delta)^2 +2)w_0 + 4w_0]/8$

$=[(1+3\Phi)A + (2\ \text{-}\ 3\alpha_{LU}(1\text{-}\Delta)^2\,)w_0]/8,$

$q_2=[(1\text{-}\Phi)A + \alpha_{LU}(1\text{-}\Delta)\{(1+3\Phi)A + (3\alpha_{LU}\,(1\text{-}\Delta)^2 + 2)w_0]/[6\alpha_{LU}\,(1\text{-}\,\Delta)\} + w_0\ \text{-}\ 3w_0)]/4$

$=[6(1\text{-}\Phi)A +(1+3\Phi)A + 3\alpha_{LU}(1\text{-}\Delta)^2\,)w_0\ \text{-}\ 12w_0]/24$

$=[(7\text{-}3\Phi)A + (10\ \text{-}\ 3\alpha_{LU}(1\text{-}\Delta)^2\,)w_0]/24,$

$q_3=[(7\text{-}3\Phi)A + (10\ \text{-}\ 3\alpha_{LU}(1\text{-}\Delta)^2\,)w_0]/24.$

B) Union firm as innovation looser (then as firm 2):

Firms choses q_i to maximise profits while taking w_i and the competitor's production (q_j) as given, i.e., $\partial \Pi_i/\partial q_i=0$. Note that since the union firm now is firm 2 the α_i 's change and thus equation 3) is rewritten:

6) $q_1=[(1+3\Phi)A + \alpha_{LU}\,w_2 + w_3\ \text{-}\ 3(1\text{-}\Delta)w_1)]/4,$

$q_2=[(1\text{-}\Phi)A + (1\text{-}\Delta)w_1 + w_3\ \text{-}\ 3\,\alpha_{LU}\,w_2)]/4,$

$q_3=[(1\text{-}\Phi)A + (1\text{-}\Delta)w_1 + \alpha_{LU}\,w_2\ \text{-}\ 3w_3)]/4.$

Since firm 2 is the local bargaining union firm, firms 1 and 3 set wages competitively, i.e. $w_1= w_0$, $w_3= w_0$.

For firm 2, we get:

$\max_{w1}\,(1\text{-}\,\Delta)q_2\,(w_2\text{-}w_0) \rightarrow .0=\partial\ \{\ [\ [(1\text{-}\Phi)A + (1\text{-}\,\Delta)w_1 + w_3\ \text{-}\ 3\alpha_{LU}w_2)]/4]\ (w_2\text{-}w_0)\ \}/\partial_{\,w2}$

$\rightarrow .[-3\,\alpha_{LU}\,(w_2\text{-}w_0)]+\ [(1\text{-}\Phi)A + (1\text{-}\Delta)w_1\ \ \text{-}\ 3\alpha_{LU}w_2) + w_3]/4]=0$

$\rightarrow w_2=[(1\text{-}\Phi)A + (3\alpha_{LU}\ \text{-}\ \Delta + 2)w_0]/[6\alpha_{LU}]$

Once again, we can express the firms' production levels as a function of the competitive wage, i.e., by plugging the expressions for wages into 6) and simplify as we did for the case when firm 1 was the union firm:

8) $q_1=[(7+17\Phi)A - (10 - 3\alpha_{LU} - 17\,\Delta)\, w_0]/24,$

$q_2=[(1-\Phi)A + (10 - 3\alpha_{LU} - 17\,\Delta)\, w_0)]/8,$

$q_3=[(7-7\Phi)A + (10 - 3\alpha_{LU} + 7\,\Delta)\, w_0]/24.$

On innovation incentives

Haucap and Wey (2004) established that when only labour productivity enhancing innovations were possible, Δ would have to be strictly less than 1/3 (or $w_0 <(1- 3\Delta)A/(1- \Delta)^2$). This assumption was necessary to assert that the non-innovating firm was not driven out of the market (to avoid corner solutions). With competitive or local union set wages, this is less of a problem (the local union sets wages conditional on survival). For comparison reasons, we just limit Δ to be strictly less than 1/3. We focus attention on jointly moderate innovations, i.e., we also limit Φ to be strictly less than 1/3.

While we let Φ and Δ vary, we do not allow the employer to invest differentially in Φ and Δ, although we acknowledge that it might be easier to influence product demand considerably (by refining existing product or introducing new ones) compared to improving labour productivity dramatically. Furthermore, as seen previously the presence of union voice effects makes product innovation more profitable than process innovation for the union firm.

The implementation costs, $I(\Delta, \Phi, \gamma_i)$, depend on pay-setting scheme (expressed by the subscript i), where lower values for γ_i imply lower implementation costs. For simplicity, in the competitive case we set $\gamma_c =1$. In line with the findings from the literature review, we assume that $\gamma_{LU} <1$. Each player (firm) is equally likely as the winner, thus you win or lose with probability of one third. However, the union firm will be the looser twice.

The expected profit from participating in the innovation race can thus be expressed:

9) Union firm: $(1/3)\, \Pi_1(\Phi,\Delta)+ (2/3)\Pi_2(0,0) - (1/3)[\, I(\Phi,\Delta, \gamma_{LU})].$

Competitive firm, union firm looser: $(1/3)\, \Pi_1(\Phi,\Delta)+ (2/3)\Pi_2(0,0) - (1/3)[\, I(\Phi,\Delta, \gamma_c)].$

Competitive firm, union firm winner: $(2/3)\, \Pi_1(\Phi,\Delta)+ (1/3)\, \Pi_3(0,0)] - (2/3)[\, I(\Phi,\Delta, \gamma_c)].$

This expected profit from participating in the innovation race will have to exceed the profit of abstaining:

10) Union (A): $(1/3)[\Pi_i(\Phi,\Delta) - I(\Phi,\Delta, \gamma_{LU})] + (2/3)\Pi_j(0,0) > \Pi_j(0,0)$,

Competitive(B): $(1/3)[\Pi_i(\Phi,\Delta) - I(\Phi,\Delta, \gamma_c)] + (2/3)\Pi_j(0,0) > \Pi_j(0,0)$,

Competitive(C): $(2/3)[\Pi_i(\Phi,\Delta) - I(\Phi,\Delta, \gamma_c)] + (1/3)\Pi_j(0,0) > \Pi_j(0,0)$,

(by not participating, a firm achieves the same profits as by losing the race). In other words, the profit gain from these innovations will have to cover the costs associated with implementing the innovations:

11) $$\Pi_i(\Phi,\Delta) - \Pi_j(0,0) - I(\Phi,\Delta, \gamma_i) > 0.$$

Let us assume that this constraint is satisfied, i.e., the gain from these innovations by assumption exceeds the costs associated with participating in the innovation race. Since $\Pi_i = q_i^2$ for i=1,2,3 we can decompose the operating profit differentials for the firms depending on being innovation winner(W) or loser(L): $\Gamma = \Pi^W_i - \Pi^L_i = q^W{}_i^2 - q^L{}_i^2 = (q^W_i + q^L_j)(q^W_i - q^L_j)$, where Γ denotes the profit differential. More explicitly, we find:

12)Union: $\Gamma^U = (1/(8^2)\,[(2+2\,\Phi)A + (4-6\alpha_{LU}-\Delta+3\alpha_{LU}\Delta)\,w_0\,]\,[(4\,\Phi A + \Delta(1+3\,\alpha_{LU})\,w_0\,]$,

Comp: $\Gamma^{CB} = (1/(3^2 8^2)[(14+14\Phi)A - (20-17\Delta-3\alpha_{LU}\Delta)w_0\,]\,[(20\Phi A + (6\alpha_{LU}+17\Delta-3\alpha_{LU}\Delta)w_0]$,

Comp: $\Gamma^{CC} = (1/(3^2 8^2)[(14+10\Phi)A - (20-10\Delta-6\alpha_{LU}\Delta)w_0\,]\,[24\Phi A + 24\Delta w_0]$.

To repeat, Γ^U compares the profit differential arising from when the union firm wins the innovation race and when the firm loses the innovation race. Γ^{CB} compares the profit differential arising from when the competitive firm wins the innovation race and when the competitive firm loses the innovation race to the union firm. Γ^{CC} compares the profit differential arising from when the competitive firm wins the innovation race and when the competitive firm loses the innovation race to a competitive firm.

Can we rank the pay schemes with respect to the Γs? Yes, but the ranking depends on the size of α_{LU}. On one hand, if no voice-effect exists, i.e., $\alpha_{LU}=1$, then $\Gamma^U < \Gamma^{CB}$ and $\Gamma^U < \Gamma^{CC}$. This is seen since

13)Union: $\Gamma^U = (1/(8^2)\,[(2+2\,\Phi)A + (4-6-\Delta+3\Delta)\,w_0\,]\,[(4\,\Phi A + \Delta(1+3)\,w_0\,]$,

Comp: $\Gamma^{CB} = (1/(3^2 8^2)[(14+14\Phi)A - (20-17\Delta-3\Delta)w_0\,]\,[(20\Phi A + (6+17\Delta-3\Delta)w_0]$,

Comp: $\Gamma^{CC} = (1/(3^2 8^2)[(14+10\Phi)A - (20-10\Delta-6\Delta)w_0\,]\,[24\Phi A + 24\Delta w_0]$,

which can be rewritten:

14)Union: $\Gamma^U = (3^2/(3^2 8^2)\,[(2+2\,\Phi)A - (2-2\Delta)\,w_0\,]\,[(4\,\Phi A + 4\Delta w_0\,]$, Comp: Γ^{CB}= $(1/(3^2 8^2)[(14+14\Phi)A-(20-20\Delta)w_0]\,[(20\Phi A+(6+14\Delta)w_0]$,

Comp: Γ^{CC}= $(1/(3^2 8^2)[(14+10\Phi)A-(20-16\Delta)w_0]\,[24\Phi A+24\Delta w_0]$.

Or:

15)Union: $\Gamma^{U}=(1/(3^2 8^2)\,[(6+6\Phi)A-(6-6\Delta)\,w_0]\,[(12\,\Phi A+12\Delta w_0]$,

Comp: Γ^{CB}= $(1/(3^2 8^2)[(14+14\Phi)A-(20-20\Delta)w_0]\,[(20\Phi A+(6+14\Delta)w_0]$,

Comp: Γ^{CC}= $(1/(3^2 8^2)[(14+10\Phi)A-(20-16\Delta)w_0]\,[24\Phi A+24\Delta w_0]$.

Since the term $(1/(3^2 8^2)$ is found in all three expressions, this term can be ignored when comparing these.

Then we see that $[(6+6\Phi)A-(6-6\Delta)\,w_0] < [(14+14\Phi)A-(20-20\Delta)w_0]$ and $[(6+6\Phi)A-(6-6\Delta)\,w_0] < [(14+10\Phi)A-(20-16\Delta)w_0]$. Similarly, we see that $[(12\,\Phi A+12\Delta w_0] < [(20\Phi A+(6+14\Delta)w_0]$ and $[(12\,\Phi A+12\Delta w_0] <= [(24\Phi A+(24\Delta)w_0]$. Thus both terms in the union case is less than the similar terms for the competitive cases. Thus when no voice-effect exists, i.e., $\alpha_{LU}=1$, then $\Gamma^{U} < \Gamma^{CB}$ and $\Gamma^{U} < \Gamma^{CC}$.

On the other hand, if $\alpha_{LU}=0$, then depending on the relationship between A and w_0 then $\Gamma^{U} > \Gamma^{CB}$ and $\Gamma^{U} > \Gamma^{CC}$.

16)Union: $\Gamma^{U}=(1/(8^2)\,[(2+2\,\Phi)A+(4-\Delta)\,w_0]\,[(4\Phi A+\Delta w_0]$,

Comp: Γ^{CB}= $(1/(3^2 8^2)[(14+14\Phi)A-(20-17\Delta)w_0]\,[(20\Phi A+17\Delta w_0]$,

Comp: Γ^{CC}= $(1/(3^2 8^2)[(14+10\Phi)A-(20-10\Delta)w_0]\,[24\Phi A+24\Delta w_0]$.

Or :

17)Union: $\Gamma^{U}=(1/(3^2 8^2)\,[(6+6\Phi)A+(12-3\Delta)\,w_0]\,[(12\Phi A+3\Delta w_0]$,

Comp: Γ^{CB}= $(1/(3^2 8^2)[(14+14\Phi)A-(20-17\Delta)w_0]\,[(20\Phi A+17\Delta w_0]$,

Comp: Γ^{CC}= $(1/(3^2 8^2)[(14+10\Phi)A-(20-10\Delta)w_0]\,[24\Phi A+24\Delta w_0]$.

If $3>A/w_0$ then union dominates the competitive solutions.