Price competition and the effects of labour union on innovation[†]

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Abstract: In contrast to the conventional belief that labour union intervention reduces firms' incentives to innovate, I show that this view may not hold true when the firms compete in prices. I find that the presence of labour union may increase firms' incentives for innovation if the worker's reservation wage is high. Further, a comparison across the unionisation structures, viz., decentralised unions and centralised union reveals that whether the firms innovate more under the former union structure or the latter, depends on the hold-up problem and the reservation wage of the workers.

Key Words: Industry-wide union; Firm-specific union; Process Innovation; Union utility

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1. Introduction

Firm's decision to innovate is considered to be a key to economic growth. There is a large body of literature that examines the factors which impede or promote innovation. While firm's decision to invest in R&D is driven by a number of factors, the role of labour unions on firm's decisions to innovate is still a topic of debate. The general consensus is that union membership in the OECD countries have declined over the past few years. Ogawa et al. (2016) report that although the union membership which is defined by the number of workers registered at a trade union, has declined in few countries, "the degree of decline is not the same in all countries; in fact, cross-country variations in membership rates have widened over time. For instance, countries such as the US (11.3% in 2011), Korea (9.7% in 2010) and Turkey (5.4% in 2010) have a low membership rate, while other countries have a high membership rate, such as Denmark (68.5% in 2010), Finland (69.0% in 2011) and Sweden (67.7% in 2011)." Visser (2006) reports that the unionisation level varies in between 20% to 50% in the UK, Canada, Italy, Ireland, Israel, Greece, Austria and Luxembourg. Studies show that unions differ substantially in between countries with respect to the degree of wage setting behaviour. Goeddeke (2010) reports that while union-firm bargaining is decentralised in USA, UK, Australia, Canada and Japan; majority of the European and Scandinavian countries involve either in sector-wide and rarely in nation-wide bargaining. In a more recent study, Ellguth et al. (2014) argue that the current trend of the unionisation structure in almost all advanced economies worldwide is more decentralised.[1]

Given the wide coverage and diversity of unionised labour market, there is a growing interest towards the effects of labour union structures on innovation. A number of studies

[1] Calmfors and Driffill (1988) Moene and Wallerstein (1997), Flanagan (1999) and Wallerstein (1999) also argue that labour unions differ with respect to the degree of wage setting centralisation. While the centralised argument is egalitarian in nature and generally makes the sufficiently substitutable workers better off (Horn and Wolinsky, 1988 and Davidson, 1988), the rigidity associated with this system is generally bad for overall economic performance (Nickell, 1997 and Siebert, 1997).

examined the implications of different organisational modes of labour union on innovation, in particular, in the context of a patent race model (Haucap and Wey, 2004), in a model of R&D competition (Calabuig and Gonzalez-Maestre, 2002), in a cooperative R&D structure (Manasakis and Petrakis, 2009), in the context of technology licensing (Mukherjee and Pennings, 2011) and in a set up where firms invest towards innovating new products (Basak and Mukherjee, 2018).[2] While these papers offer several dimensions to the bargaining literature, they share a common ground by assuming that the innovating firms compete in quantities. However, little is known how firms' incentives to innovate will be affected when they compete in prices.

I take up this issue in this paper. In particular, I examine how labour union intervention and different organisational modes of labour unions, viz., decentralised and centralised unions affect firms' innovation incentives when they compete in prices.

I adopt an oligopolistic model with two firms that hire workers from labour unions which are either decentralised or centralised in nature. If the union is decentralised, the union-firm wage bargaining takes place at the firm level whereas bargaining is industry-wide when the union structure is centralised. Firms may invest in process innovation, which reduces their labour requirements in the production process. Considering a competitive labour market as the benchmark, I show that whether the innovation incentives of the firms are higher under no union or labour union structures depend on the reservation wage of the workers. Typically, the presence of labour union provides higher incentives for innovation compared to competitive labour market if the reservation wage of the workers is high. A comparison across the union structures (viz., decentralised unions and centralised union) reveals that whether the firms

[2] In contrast to these papers, earlier works have shown the impacts of union bargaining power. See Grout (1984) and Van der Ploeg (1987) for surveys, and Tauman and Weiss (1987) and Ulph and Ulph (1994 and 2001) for more recent contributions on this strand of literature. The monopoly input supplier in Degraba (1990), which shows the impact of upstream pricing strategy on downstream innovation, can be interpreted as a centralised union.

innovate more under the former union structure or the latter, depends on the hold-up problem[3] and reservation wage of the workers.

By evaluating my findings in comparison to the existing theoretical literature, I find that the results are in stark contrast to Haucap and Wey (2004) and Calabuig and Gonzalez-Maestre (2002). Haucap and Wey (2004) show that if the centralised union charges a uniform wage rate, then the uniformity rule is more effective in constraining unions' hold-up potential and leads to higher incentives for innovation under a centralised union than decentralised unions; however, if the centralised union discriminates wage, it helps the union to exploit its hold-up problem at its maximum and the innovation incentive can be lower under a centralised union. Calabuig and Gonzalez-Maestre (2002) show that the hold-up problems are affected by the nature of innovation which may make production by the non-innovating firm unprofitable. They find that when innovation is drastic (non-drastic) in nature, the innovation incentive is higher under centralised union (decentralised unions). Manasakis and Petrakis (2009) show that the degree of knowledge spillover and cooperation in R&D affect the hold-up problems created by the unionisation structures. They argue that under non-cooperative R&D, the incentive for innovation is higher under decentralised unions if knowledge spillovers are high; whereas the incentive for innovation is always higher under decentralised labour unions under cooperative R&D. In Mukherjee and Pennings (2010), the hold-up problems are present both in the innovation stage and in the technology licensing stage. Under licensing ex-post innovation, competition between the unions under decentralised unions is more effective in softening the hold-up problem, thus creating a stronger incentive for licensing under decentralised unions. The gain from licensing tends to increase the incentive for innovation

[3] The innovating firms fear to make additional investments towards innovation as there is always a possibility that the labour union will appropriate a share of its profit. This kind of opportunistic behaviour on the union’s part is more commonly known as hold-up problem in the literature (Williamson; 1975 and Milgrom and Roberts; 1992).

under decentralised unions by reducing the negative effects of the hold-up problem under decentralised unions.

While the main focus of the above papers remained on the comparison of firms' innovation incentives across the unionised structures (viz., decentralised unions and centralised union), this paper makes a leap forward by comparing the competitive labour market scenario with the unionised labour market. The result that the presence of labour union provides higher incentive for innovation compared to no labour union when the worker's reservation wage is high, is driven by the following effects. First, innovation, in this paper, creates a direct positive effect on the innovating firm's profit as it steals market share from its rival. This is popularly known as business stealing effect. Secondly, as the firms compete in prices, innovation also creates a strategic effect which is negative.[4] Finally, the presence of labour union gives rise to a hold-up problem that arises through increased wage demand due to higher bargaining power of the labour union. I find that when the reservation wage of the workers is high, the labour unions demand even higher wage. As a result, the innovating firm sets a higher market price to compensate this increased wage demand. I name this a price effect. This price effect plays a crucial role in offsetting the negative wage effect, i.e., the hold-up problem and the strategic effect which results in higher incentives for innovation under labour union compared to a competitive labour market. This result is in stark contrast to the conventional belief that labour union interventions always reduce the incentives for innovation.

A comparison across the labour union structures shows that whether the innovation incentives are higher under a centralised union or decentralised unions depend on the severity of the hold-up problem under each unionised structure and how effectively the price effect (discussed above) supresses the hold-up problem. I find that when the reservation wage is high,

[4] Note that, when the firms compete in quantities, the strategic effect is positive which increases the profit of the innovating firm and hence, increases the likelihood of higher innovation incentives in the presence of labour union.

the price effect under a centralised union dominates the hold-up problem. As a result, the innovation incentives are higher under a centralised union than under decentralised unions. In all other cases, decentralised unions provide higher innovation incentives as the hold-up problem is otherwise too severe under a centralised union because of its monopolised nature of wage setting behaviour.

The remainder of the paper is organised as follows. Section 2 describes the model and derives equilibrium output levels. Section 3 considers the wage setting game under no labour union, decentralised unions and a centralised union respectively. Section 4 demonstrates the investment game. Section 5 shows the effects of labour union and different labour unionisation structures on the incentive for innovation. Section 6 concludes.

2. Model outline

Consider an industry populated with two firms which I index by $i = 1,2.$ The firms produce horizontally differentiated products. To avoid analytical complexity, I assume that production requires only labour and the firms incur no other cost of production other than the labour cost (wage). Initially the technology is such that the firms require one unit of labour to produce one unit of output (q_i), where $i = 1,2.$ However, each firm may undertake innovation to reduce its labour requirement. I assume that innovation is costly and the innovating firm invests $k > 0$ to reduce its labour coefficient to ϕ from unity where $\phi \in (0,1)$. This model is similar to Calabuig and Gonzalez-Maestre (2002) with the exception that the firms compete in prices.

I assume that the workers are unionised, and each firm hires workers from the labour unions that are either decentralised or centralised in nature. Like many other notable papers (eg. Bughin and Vannini, 1995, López and Naylor, 2004, Calabuig and Gonzalez-Maestre, 2002 and Haucap and Wey, 2004 and Mukherjee and Pennings, 2011), I consider a 'right-to-manage' model of labour union where the firms and the union(s) bargain over wages and the firms hire workers according to their needs.[5] In order to capture the maximum effect of labour union and to have better insights on the hold-up problem, following Calabuig and Gonzalez-Maestre (2002) and Haucap and Wey (2004), I assume that the labour unions have full bargaining power in wage determination. For an effective comparison of the wage effects under different union structures, I consider a competitive labour market as a benchmark where the workers receive a reservation wage, $r > 0$.

On the demand side, I consider the representative consumer's utility function as

$$V(q,m) = \sum_i q_i - \frac{1}{2}\sum_i q_i^2 - \gamma \sum_{\substack{j \\ i \neq j}} q_i q_j + m \tag{1}$$

where m is the numeraire good and $\gamma \in [0,1]$ measures the degree of product differentiation. If $\gamma = 1$, the goods are perfect substitutes, and if $\gamma = 0$, the goods are isolated. As the firms produce differentiated products, I restrict my analysis to $\gamma \in [0,1)$. The utility maximisation generates the following inverse and direct demand functions for good i

$$P_i = 1 - q_i - \gamma q_j \tag{2}$$

$$q_i = \frac{(1-\gamma)a - P_i + \gamma P_j}{1-\gamma^2} \tag{3}$$

where P_i and q_i are price and output of product i and $i, j = 1,2;\ i \neq j.$

I consider a three-stage game. At stage 1, the firms decide whether to invest in innovation. At stage 2, the wages are determined either by the decentralised unions or a

[5] The wage determination, however, could take the form of efficient bargaining where the labour unions and the firms bargain over the wage rate and employment level simultaneously. The right-to-manage model gained more popularity in the policy circle compared to the efficient bargaining model because it is difficult to prescribe a contract which constitute an efficient combination of wages and employment. As reported by Oswald (1993), in response to his questionnaire: "Does your union normally negotiate over the number of jobs as well as over wages and condition?" only two US respondents (out of 19) and only three British respondents (out of 18) answered assertive. Layard et al. (1991) also offered some arguments in favour of this issue. He mentioned that bargaining does not generally takes place over employment simply because the existing workers only care about their own job securities rather than paying much attention to the employment level of the firms. In light of this argument, I adopt a right-to-manage model for my analysis.

centralised union. At stage 3, the firms choose their prices simultaneously and the profits are realised. I solve the game through backward induction.

2.1 Equilibrium price and output

I begin the discussion at stage 3 where the firms compete in prices and maximise their profit levels. For the ease of analysis, I will derive the equilibrium price levels and the corresponding levels of output under three possible constellations: (i) neither firm innovates, (ii) only one firm innovates, and, (iii) both firms innovate. If firm *i* refrains from innovation, it maximises $\pi_i = (P_i - w_i) q_i$ to set its price. And, if firm *i* chooses to invest in innovation, its profit maximisation problem reads as $\pi_i = (P_i - \phi w_i) q_i - k$.

First, I consider the case where neither firm invests in innovation. In this situation, the equilibrium price charged by the i^{th} firm is:

$$\hat{P}_i = \frac{(2+\gamma)(1-\gamma) + 2w_i + \gamma w_j}{4-\gamma^2} \tag{4}$$

and, the corresponding output level is

$$\hat{q}_i = \frac{(2+\gamma)(1-\gamma) - (2-\gamma^2) w_i + \gamma w_j}{(4-\gamma^2)(1-\gamma^2)} \tag{5}$$

Now, consider the case where only one firm innovates. For notational convenience, I denote the innovating firm by '*iv*' and the non-innovating firm by '*nv*'. Under this scenario, the resulting equilibrium price and output levels are respectively

$$P_{iv} = \frac{(2+\gamma)(1-\gamma) + 2\phi w_{iv} + \gamma w_{nv}}{4-\gamma^2} \tag{6}$$

$$P_{nv} = \frac{(2+\gamma)(1-\gamma) + \gamma\phi w_{nv} + 2w_{iv}}{4-\gamma^2} \tag{7}$$

and,

$$q_{iv} = \frac{(2+\gamma)(1-\gamma)-(2-\gamma^2)\phi w_{iv} + \gamma w_{nv}}{(4-\gamma^2)(1-\gamma^2)} \tag{8}$$

$$q_{nv} = \frac{(2+\gamma)(1-\gamma)+\gamma\phi w_{nv} - (2-\gamma^2) w_{iv}}{(4-\gamma^2)(1-\gamma^2)} \tag{9}$$

Finally, where both firms engage in innovation, the equilibrium price and output yield

$$\overline{P}_i = \frac{(2+\gamma)(1-\gamma)+2\phi w_i + \gamma\phi w_j}{4-\gamma^2} \tag{10}$$

$$\overline{q}_i = \frac{(2+\gamma)(1-\gamma)-(2-\gamma^2)\phi w_i + \gamma\phi w_j}{(4-\gamma^2)(1-\gamma^2)} \tag{11}$$

3. Wage determination

I now analyse stage 2 where I define and solve the wage setting game and derive the respective equilibrium wage rates conditional on the innovation strategies adopted by the firms. To this end, I will consider three different scenarios: no labour union, decentralised unions and a centralised union. For the ease of analysis, I will regularly use $\rho = n, d, c$ in the superscripts to indicate no union, decentralised unions and a centralised union respectively.

3.1 No Labour Union: The Benchmark

In order to exercise an effective comparison of innovation incentives under different union structures, I set a benchmark case where the labour market is perfectly competitive. In the absence of labour union intervention, the workers earn a competitive wage rate $r > 0$. [6] We, however, assume that $r < 1$ to ensure the positivity of equilibrium wage rate, output and profit.

[6] I kept the model general by assuming $r > 0$ and this assumption is in contrast to Calabuig and Gonzalez-Maestre (2004) who assume that $r = 1$ to keep the model tractable.

3.2 Decentralised Labour Unions

Under decentralised labour unions, the i^{th} firm-specific union where $i=1,2,$ determines wage by maximising the union utility $\Omega_i=(w_i-r)L_i,$ where L_i is the labour demand faced by the i^{th} firm.

I begin with the case where neither firm innovates. The resulting output levels are demonstrated in expression (5). The i^{th} union determines the equilibrium wage w_i by maximising $\Omega_i=(w_i-r)L_i=(w_i-r)\hat{q}_i.$ The utility maximisation problem leads to the equilibrium wages as

$$\hat{w}_i^d=\hat{w}_j^d=\frac{(1-\gamma)(2+\gamma)+r\left(2-\gamma^2\right)}{4-\gamma-2\gamma^2} \tag{12}$$

Next, consider the scenario where one firm (say firm *i*) innovates and its rival (firm *j*) does not. The corresponding output levels are shown in expressions (8)-(9). Firm *i* (firm *j*) determines its firm-specific wage, w_i $\left(w_j\right)$ by maximising the objective function $\Omega_i=(w_i-r)L_i=(w_i-r)\phi q_{iv}$ (and $\Omega_j=\left(w_j-r\right)L_j=\left(w_j-r\right)q_{nv}$ resp.). Maximisation leads to the following equilibrium wages for the innovating and non-innovating firms respectively:

$$w_{iv}^d=\frac{(1-\gamma)(2+\gamma)\left(4+\gamma-2\gamma^2\right)+r\left(2-\gamma^2\right)\left(\gamma+4\phi-2\gamma^2\phi\right)}{\phi\left(4+\gamma-2\gamma^2\right)\left(4-\gamma-2\gamma^2\right)} \tag{13}$$

$$w_{nv}^d=\frac{(1-\gamma)(2+\gamma)\left(4+\gamma-2\gamma^2\right)+r\left(2-\gamma^2\right)\left(4-2\gamma^2+\gamma\phi\right)}{\left(4+\gamma-2\gamma^2\right)\left(4-\gamma-2\gamma^2\right)} \tag{14}$$

Finally, when both firms innovate, the output levels are equivalent to the expressions stated in equation (11). The i^{th} firm determines the wage to maximise the expression $\Omega_i=(w_i-r)L_i=(w_i-r)\phi\overline{q}_i.$ The equilibrium wages are

$$\overline{w}_i^d=\overline{w}_j^d=\frac{(2+\gamma)(1-\gamma)+r\left(2-\gamma^2\right)\phi}{\phi\left(4-\gamma-2\gamma^2\right)} \tag{15}$$

3.3 A Centralised Labour Union

I now turn the discussion to centralised union. Analogous to the case of decentralised labour unions, I first consider the situation where neither firm innovates. The equilibrium wages are determined by maximising $\Omega = \sum (w_i - r)\hat{q}_i$ which yield the equilibrium wages as

$$\hat{w}_i^c = \hat{w}_j^c = \frac{1+r}{2} \tag{16}$$

If only one firm (say firm *i*) innovates while the other (firm *j*) does not, the wages of the innovating and non-innovating firms are determined by maximising $\Omega = (w_i - r)\phi q_{iv} + (w_j - r) q_{nv}$. The resulting equilibrium wages are

$$w_{iv}^c = \frac{1+r\phi}{2\phi} \tag{17}$$

$$w_{nv}^c = \frac{1+r}{2} \tag{18}$$

Finally, if both firms engage in process innovation, the maximisation problem $\Omega = \sum (w_i - r)\phi\overline{q}_i$ gives the equilibrium wages as

$$\overline{w}_i^c = \overline{w}_j^c = \frac{1+r\phi}{2\phi} \tag{19}$$

To have better insights on the hold-up problem I compute the wage differentials across the union structures. The following Lemma is immediate from the above discussion.

Lemma 1: *(a) A centralised union charges a higher wage rate compared to decentralised unions irrespective of whether neither firm innovates, i.e.,* $\hat{w}^c > \hat{w}^d$ *or both firms innovate, i.e.,* $\overline{w}^c > \overline{w}^d$ *or only one firm innovates, i.e.,* $w_{iv}^c > w_{iv}^d$.

(b) The increase in wage under a centralised union is higher when both firms innovate compared to when only one firm innovates.

Proof: See Appendix A.

The intuition of the above lemma goes as follows. It is straightforward that due to the monopoly nature of the centralised union, its rent seeking behaviour is also higher than that under decentralised unions. Therefore, the former union structure charges a higher wage compared to the latter irrespective of the innovation strategies adopted by the firms.

Further, when both firms innovate the rent seeking behaviour of the centralised union is more prominent as it can appropriate rent from both innovating firms. However, when only one firm innovates, the rent seeking behaviour of the centralised union is not so severe as it moderates its wage demand to allow the host firm to maintain its market.

The wage effects discussed in Lemma 1 help to investigate how the severity of hold-up problems across unions vary in accordance with the innovator's profit levels. In the next section, I demonstrate the investment game under the three regimes $\rho = n, d, c$ and find out the respective profit levels.

4. The Investment Game

I now discuss stage 1 where the firms determine their investment levels towards innovation. Table 1 summarises the possible strategies of each firm and the realised profits conditional on the innovation decisions. Let $\pi_i^\rho(.,.)$ denotes the i^{th} firm's profit in the product market where $i = 1, 2$ and the first (second) argument in $\pi_i^\rho(.,.)$ shows the labour co-efficient of firm *i* (firm *j*). For example, $\pi_i^\rho(\phi, 1)$ shows the i^{th} firm's profit in the product market when firm *i* innovates and firm *j* does not.

Table 1

	R&D	No R&D
R&D	$\pi_i^\rho(\phi;\phi)-k$, $\pi_j^\rho(\phi;\phi)-k$	$\pi_i^\rho(\phi;1)-k$, $\pi_j^\rho(\phi;1)$
No R&D	$\pi_i^\rho(1;\phi)$, $\pi_j^\rho(1;\phi)-k$	$\pi_i^\rho(1;1)$, $\pi_j^\rho(1;1)$

The respective pay-off tables under no labour union, decentralised labour unions and a centralised labour union are reported in Appendix B.1, B.2 and B.3 respectively.

From Table 1 I derive the Nash equilibria of the innovation game for different investment costs.[7] The incentive for a firm to innovate, given the strategy of its competitor is the difference in profits between innovation and no innovation. I define the investment costs at which no firm innovates, both firms innovate and only one firm innovates. Accordingly, which Nash equilibrium is achieved depends on the size of the cost of innovation, *k*. I report the Nash equilibria under no union, decentralised unions and a centralised union in Lemma 2.

Lemma 2: *The following investment rankings hold true under no labour union, decentralised unions and centralised union respectively*

(a) Both firms innovate if $k < k_L^\rho$

(b) Only one firm innovates if $k_L^\rho < k < k_H^\rho$

(c) Neither firm innovates if $k_H^\rho < k$.

[7] There is also a mixed strategy equilibrium where the firms randomise on innovation and no innovation. However, I focus only on the pure strategy equilibria in this paper.

The respective values of k_L and k_H under no union, decentralised union and centralised union are reported in the Appendix.

Proof: See Appendix (A.2).

If $k < k_L^\rho$, both firms innovate, and I denote this equilibrium by (RD, RD). If $k_H^\rho < k$, neither firm innovates, and I denote this equilibrium by (No RD, No RD). If $k_L^\rho < k < k_H^\rho$, only one firm innovates, and I denote the equilibrium by (RD, No RD) if only firm *i* innovates and firm *j* does not and by (No RD, RD) if firm *i* does not innovate and firm *j* innovates.

In line with Roy Chowdhury (2005), the incentive for innovation is driven by two effects – strategic benefit and non-strategic benefit of innovation. A firm's non-strategic benefit, k_H^ρ (strategic benefit, k_L^ρ) from innovation is given by its payoff from innovation, net of its payoff from no innovation, when the competitor firm does not innovate (innovates). Formally, I define firm *i*'s non-strategic and strategic benefits by $k_L^\rho \le \pi_i^\rho(\phi,\phi) - \pi_i^\rho(1,\phi)$ and $k_H^\rho \le \pi_i^\rho(1,1) - \pi_i^\rho(\phi,1)$ respectively. Therefore, firm *i* does not innovate if its gross non-strategic benefit from innovation is less than the cost of innovation, i.e., $k_H^\rho < k$ and firm *i* innovates if its gross strategic benefit from innovation is greater than the cost of innovation, i.e., $k < k_L^\rho$. Since the firms are symmetric, similar arguments hold for the rival firm. Lemma 2 shows that the non-strategic benefit from innovation is higher than the strategic benefit from innovation, i.e., $k_L^\rho < k_H^\rho$.

5. The effects of the unionisation structures

I now focus on the effects of labour union structures on innovation. To make an effective comparison, first, I compare the innovation incentives under no union and unionised structures.

Next, I compare the innovation incentives across the union structures, viz., decentralised unions and a centralised union.

Proposition 1: A comparison between no union and the decentralised unions gives the following investment rankings: (a) $k_L^n < k_L^d$ when $r > r^d$ and the reverse holds true when $r < r^d$ and, (b) $k_H^d < k_H^n$ for $r \in (0,1)$.

The respective values of k_L, k_H *and* r^d *under no union and decentralised unions are reported in the Appendix.*

Proof: See Appendix (C.1).

The above proposition implies that the strategic benefit from innovation is higher under decentralised unions compared to no union, i.e., the presence of decentralised unions increases the region where both firms innovate if the reservation wage is significantly high and the opposite is true when the reservation wage is low. The non-strategic benefit from innovation, on the other hand, is lower under decentralised unions than no union, i.e., the presence of decentralised unions increases the region where no firm innovates. The intuition goes as follows.

Let me begin with the case of competitive labour market where innovation helps the innovating firm to increase its profit by stealing business from its rival. I call this a *business stealing effect*. Secondly, a reduction in its marginal cost induces it to set a lower price which in turn reduces the rival's price. A reduction in rival's price reduces its own profit. I name this a *strategic effect.* Finally, when the market is unionised, an additional *wage effect* arises through higher bargaining power of the labour unions. Clearly, this wage effect dampens firm's profit. Therefore, whether the firms innovate more under a unionised structure compared to no union, depends on the relative strengths of these effects and the *price effect* that I discuss below.

First, I consider a firm's strategic benefit from innovation, k_L which is given by its payoff from innovation, net of its payoff from no innovation when the rival firm innovates. It follows from eq.(14) and (15) that as the reservation wage increases, the decentralised unions demand a comparatively higher wage rate when the host firm innovates compared to when it does not innovate (given that the rival firm innovates). The host firm compensates this increased wage demand by setting a higher price in the market which in turn helps to increase its profit. I call this a *price effect*. As follows, when the reservation wage is high (i.e., $r > r^d$), this price effect together with the business stealing effect strictly dominate the strategic effect and the wage effect. As a result, the incentives for both firm innovating are higher under decentralised unions than under no union. However, if the reservation wage rate is low (i.e., $r < r^d$), the price effect is not strong enough to dominate the strategic effect and the wage effect. Therefore, in this case, innovation incentives are lower in the presence of decentralised unions.

Next, consider a firm's non-strategic benefit from innovation, k_H which is given by its pay-off from innovation, net of its payoff when the rival firm does not innovate. Note that, the business stealing effect is much more prominent when the host firm innovates as the innovating firm is able to capture a bigger market from its non-innovating rival through innovation. This instigates the decentralised unions to demand even higher wage rate to the innovating firm. In this case, the price effect is not strong enough to compensate the negative wage effect and strategic effect. As a consequence, intervention of decentralised union discourages the host firm to innovate which results in an increase in the region where no firm innovates.

Proposition 2: A comparison between no union and a centralised union gives the following investment rankings: (a) $k_L^n < k_L^c$ when $r > r^c$ and the reverse holds true when $r < r^c$ and, (b) $k_H^c < k_H^n$ for $r \in (0,1)$. *The respective values of* k_L, k_H *and* r^c *under no union and centralised union are reported in the Appendix.*

Proof: See Appendix (C.2).

The intuitions for proposition 2 are similar to that of proposition 1.

Finally, a comparison between decentralised unions and a centralised union yields the following.

Proposition 3:

(a) A comparison between a centralised union and decentralised unions gives the following investment rankings: (a) $k_L^c < k_L^d$ and, (b) $k_H^d < k_H^c$ when $r > r^*$ and the reverse holds true when $r < r^*$. *The respective values of* k_L, k_H *and* r^* *under the centralised union and decentralised unions are reported in the Appendix.*

Proof: See Appendix (C.3).

The above implies that the strategic benefit from innovation is higher decentralised unions compared to a centralised union, i.e., the presence of decentralised unions increases the region where both firms innovate. The non-strategic benefit from innovation, on the other hand, is lower under decentralised union compared to a centralised union, i.e., the decentralised unions increase the region where no firm innovates. The intuition is as follows.

First, I consider the firm's strategic benefit from innovation, k_L. Recall from Lemma 1 that the innovating firm pays a higher wage rate to the workers under a centralised union than under decentralised unions irrespective of whether one firm innovates or both firms innovate.

Also, the increase in wage demand under a centralised union is higher when both firms innovate compared to when one firm innovates. The *hold-up* problem being severe under a centralised union, I get that the strategic incentives for innovation is higher under decentralised unions than under a centralised union.

Now, let me consider the firm's non-strategic benefit from innovation. As noted above, the wage demand under a centralised union is still high compared to decentralised unions. However, when the reservation wage is high (i.e., $r > r^*$), the price effect (discussed in proposition 1) that arises due to higher wage demand is also high under a centralised union. As follows, the price effect under a centralised union dominates the negative wage demand compared to decentralised unions. This is why the innovation incentives are higher under a centralised union when the reservation wage is high. On the other hand, when the reservation wage is low (i.e., $r < r^*$), the price effect under a centralised union is no longer strong enough to compensate the negative wage effect. Therefore, innovation incentives, in this case, are higher under decentralised unions than under a centralised union.

6. Conclusion

In this paper, I study the effects of labour union intervention and the organisational mode of labour unions on innovation. To this end, I consider decentralised unions where wage bargaining takes place at the firm level and a centralised union where negotiations occur at the industry level. I show that the common knowledge that labour union interventions always reduce firms' innovation incentives, may not hold true when the firms compete in prices. I find that if the reservation wage of the workers is sufficiently high, innovation incentives under unionised structures could be higher compared to the case where there is no labour union. Further a comparison across the unionisation structures shows that whether the incentive for innovation is higher under decentralised labour unions than a centralised union depends on the hold-up problem under the respective union structures and the reservation wage of the workers.

These results draw valuable insights for various innovation policies. During the last three decades policymakers have become increasingly concerned about the role of innovation and how they affect the firms, consumers and the society as a whole. In contrary to the conventional belief, the results suggest that the policymakers should adopt policies in support of innovation even in the presence of labour union if the workers' outside options, such as alternative income are significantly high. The reason is that higher outside income incentivises the labour unions to demand for a higher wage which the firms compensate by setting higher market price for their products. However, while the policies in support of innovation help to spur innovation and make the unionised firms better off, it comes at the expense of the consumers welfare. As a result, union intervention may reduce the welfare of the society as a whole.

The paper also suggests that if the firms are already unioinised, a decentralised labour union structure is more optimal and desirable than a centralised union as the former not only promotes innovation, but also improves welfare compared to the latter unionised structure. The reason is that due to the monopoly nature of the centralised union, the hold-up problem is severe compared to decentralised union. This result is particularly applicable to five R&D intensive countries – USA, UK, Australia, Canada, and Japan where the negotiations are decentralised and take place between firm-specific unions and their firms. The results are also in line with the current trend that the union structure in almost all advanced economies worldwide is towards more decentralisation (Ellguth et al., 2014) as decentralised unions allow for greater flexibility and quicker adjustments, which are vital in globalised economies (Hübler and Meyer, 2000).

To conclude, let me note a few possible extensions of this paper. First, one may assume a market structure where the firms allocate their budget towards both product innovation and process innovation. It would be worthwhile to examine the effects of labour union intervention on the firms' incentives to innovate. Secondly, it would be equally interesting to see how efficient bargaining model, i.e., where the union-firm negotiate over both wages and employment would affect the findings of this paper. Finally, it would be worthwhile to examine whether innovation is excessive or insufficient under the respective union structures compared to no labour union. I leave these for future research.

7. Appendix

In this Appendix, I summarise the proofs of Lemma 1 – 2, proposition 1 – 3 and report the specific profit levels and investment cut-offs under no union, decentralised unions and centralised union respectively.

Appendix A: Proofs of Lemma 1 – 2

(A.1) Proof of Lemma 1

$$\Delta\hat{w} = \hat{w}^c - \hat{w}^d = \frac{1+r}{2} - \frac{(1-\gamma)(2+\gamma)+r(2-\gamma^2)}{4-\gamma-2\gamma^2} = \frac{(1-r)\gamma}{2(4-\gamma-2\gamma^2)} > 0.$$

$$\Delta\overline{w} = \overline{w}^c - \overline{w}^d = \frac{1+r\phi}{2\phi} - \frac{(2+\gamma)(1-\gamma)+r(2-\gamma^2)\phi}{\phi(4-\gamma-2\gamma^2)} = \frac{\gamma(1-r\phi)}{2\phi(4-\gamma-2\gamma^2)} > 0.$$

$$\Delta w_{iv} = w_{iv}^c - w_{iv}^d = \frac{1+r\phi}{2\phi} - \frac{(1-\gamma)(2+\gamma)(4+\gamma-2\gamma^2)+r(2-\gamma^2)(\gamma+4\phi-2\gamma^2\phi)}{\phi(4+\gamma-2\gamma^2)(4-\gamma-2\gamma^2)}$$
$$= \frac{\gamma\left[2(1-r)(2-\gamma^2)+\gamma(1-r\phi)\right]}{2\phi(4+\gamma-2\gamma^2)(4-\gamma-2\gamma^2)} > 0.$$

And, $\Delta\overline{w} - \Delta w_{iv} = \dfrac{r\gamma(2-\gamma^2)(1-\phi)}{\phi(16-17\gamma^2+4\gamma^4)} > 0.$

(A.2) Proof of Lemma 2

Under *no union* case, I use the profit levels of firm 1 and 2 stated in *Table B.1* to derive the following equilibrium conditions:

(RD, RD), i.e., both firms innovating is an equilibrium when

$$k < k_L^n = \left(\frac{1-\gamma}{1+\gamma}\right)\left(\frac{1-r\phi}{2-\gamma}\right)^2 - \frac{\left[(2+\gamma)(1-\gamma)-r\left(2-\gamma\phi-\gamma^2\right)\right]^2}{\left(4-\gamma^2\right)^2\left(1-\gamma^2\right)}$$

$$= \frac{r\left(2-\gamma^2\right)(1-\phi)\left[2(2+\gamma)(1-\gamma)-r\left(2-\gamma^2+\left(2-2\gamma-\gamma^2\right)\phi\right)\right]}{\left(4-\gamma^2\right)^2\left(1-\gamma^2\right)}$$

(No RD, No RD), i.e., neither firm innovating is an equilibrium when

$$k > k_H^n = \frac{\left[(2+\gamma)(1-\gamma)+r\left(\gamma-\phi+\gamma^2\phi\right)\right]^2}{\left(4-\gamma^2\right)^2\left(1-\gamma^2\right)} - \left(\frac{1-\gamma}{1+\gamma}\right)\left(\frac{1-r}{2-\gamma}\right)^2$$

$$= \frac{r\left(2-\gamma^2\right)(1-\phi)\left[2(2+\gamma)(1-\gamma)-r\left(2(1+\phi)-\gamma(2+\gamma+\gamma\phi)\right)\right]}{\left(4-\gamma^2\right)^2\left(1-\gamma^2\right)}$$

(RD, No RD) or (No RD, RD), i.e., either firm innovating is an equilibrium when

$k_L^n < k < k_H^n$ where, $k_H^n - k_L^n = \dfrac{2r^2\gamma\left(2-\gamma^2\right)(1-\phi)^2}{\left(4-\gamma^2\right)^2\left(1-\gamma^2\right)} > 0.$

Under *decentralised unions*, I use the profit levels of firm 1 and 2 stated in *Table B.2* to derive the following equilibrium conditions:

(RD, RD), i.e., both firms innovating is an equilibrium when

$$k < k_L^d = \left(\frac{1-\gamma}{1+\gamma}\right)\left(\frac{\left(2-\gamma^2\right)(1-r\phi)}{(2-\gamma)\left(4-\gamma-2\gamma^2\right)}\right)^2 - \eta_2$$

$$= \frac{r\left(2-\gamma^2\right)^2(1-\phi)\left(8-9\gamma^2+2\gamma^4\right)\left[2(1-\gamma)(2+\gamma)\left(4+\gamma-2\gamma^2\right)-r\sigma_1\right]}{\left(1-\gamma^2\right)\left(4-\gamma^2\right)^2\left(16-17\gamma^2+4\gamma^4\right)^2}$$

where, $\sigma_1 = \left(8-9\gamma^2+2\gamma^4\right)+\phi\left(8-4\gamma-9\gamma^2+2\gamma^3+2\gamma^4\right).$

(No RD, No RD), i.e., neither firm innovating is an equilibrium when

$$k > k_H^d = \eta_1 - \left(\frac{1-\gamma}{1+\gamma}\right)\left(\frac{(1-r)\left(2-\gamma^2\right)}{(2-\gamma)\left(4-\gamma-2\gamma^2\right)}\right)^2$$

$$= \frac{r\left(2-\gamma^2\right)^2(1-\phi)\left(8-9\gamma^2+2\gamma^4\right)\left[2(1-\gamma)(2+\gamma)\left(4+\gamma-2\gamma^2\right)-r\sigma_2\right]}{\left(1-\gamma^2\right)\left(4-\gamma^2\right)^2\left(16-17\gamma^2+4\gamma^4\right)^2}$$

where, $\sigma_2 = \left(8-4\gamma-9\gamma^2+2\gamma^3+2\gamma^4\right)-\phi\left(8-9\gamma^2+2\gamma^4\right)$.

(RD, No RD) or (No RD, RD), i.e., either firm innovating is an equilibrium when

$k_L^d < k < k_H^d$ where, $k_H^d - k_L^d = \dfrac{2r^2\gamma\left(2-\gamma^2\right)^3\left(8-9\gamma^2+2\gamma^4\right)(1-\phi)^2}{\left(1-\gamma^2\right)\left(4-\gamma^2\right)^2\left(16-17\gamma^2+4\gamma^4\right)^2} > 0.$

Under a *centralised union*, I use the profit levels of firm 1 and 2 stated in *Table B.3* to derive the following equilibrium conditions:

(RD, RD), i.e., both firms innovating is an equilibrium when

$$k < k_L^c = \frac{1}{4}\left(\frac{1-\gamma}{1+\gamma}\right)\left(\frac{1-r\phi}{2-\gamma}\right)^2 - \frac{\left[(2+\gamma)(1-\gamma)-r\left(2-\gamma\phi-\gamma^2\right)\right]^2}{4\left(4-\gamma^2\right)^2\left(1-\gamma^2\right)}$$

$$= \frac{r\left(2-\gamma^2\right)(1-\phi)\left[2(2+\gamma)(1-\gamma)-r\left(2-\gamma^2+\left(2-2\gamma-\gamma^2\right)\phi\right)\right]}{4\left(4-\gamma^2\right)^2\left(1-\gamma^2\right)}$$

(No RD, No RD), i.e., neither firm innovating is an equilibrium when

$$k > k_H^c = \frac{\left((2+\gamma)(1-\gamma)+r\left(\gamma-\phi+\gamma^2\phi\right)\right)^2}{4\left(4-\gamma^2\right)^2\left(1-\gamma^2\right)} - \frac{1}{4}\left(\frac{1-\gamma}{1+\gamma}\right)\left(\frac{1-r}{2-\gamma}\right)^2$$

$$= \frac{r\left(2-\gamma^2\right)(1-\phi)\left[2(2+\gamma)(1-\gamma)-r\left(2(1+\phi)-\gamma\left(2+\gamma+\gamma\phi\right)\right)\right]}{4\left(4-\gamma^2\right)^2\left(1-\gamma^2\right)}$$

(RD, No RD) or (No RD, RD), i.e., either firm innovating is an equilibrium when

$k_L^c < k < k_H^c$ where, $k_H^c - k_L^c = \dfrac{r^2\gamma\left(2-\gamma^2\right)(1-\phi)^2}{2\left(4-\gamma^2\right)^2\left(1-\gamma^2\right)} > 0.$

Appendix B: Firms' pay-off tables

Table B.1: NO UNION

	R&D	No R&D
R&D	$\left(\frac{1-\gamma}{1+\gamma}\right)\left(\frac{1-r\phi}{2-\gamma}\right)^2-k,$ $\left(\frac{1-\gamma}{1+\gamma}\right)\left(\frac{1-r\phi}{2-\gamma}\right)^2-k$	$\frac{\left[(2+\gamma)(1-\gamma)+r\left(\gamma+\gamma^2\phi-2\phi\right)\right]^2}{\left(4-\gamma^2\right)^2\left(1-\gamma^2\right)}-k,$ $\frac{\left[(2+\gamma)(1-\gamma)+r\left(\gamma^2+\gamma\phi-2\right)\right]^2}{\left(4-\gamma^2\right)^2\left(1-\gamma^2\right)}$
No R&D	$\frac{\left[(2+\gamma)(1-\gamma)+r\left(\gamma^2+\gamma\phi-2\right)\right]^2}{\left(4-\gamma^2\right)^2\left(1-\gamma^2\right)},$ $\frac{\left[(2+\gamma)(1-\gamma)+r\left(\gamma+\gamma^2\phi-2\phi\right)\right]^2}{\left(4-\gamma^2\right)^2\left(1-\gamma^2\right)}-k$	$\left(\frac{1-\gamma}{1+\gamma}\right)\left(\frac{1-r}{2-\gamma}\right)^2,$ $\left(\frac{1-\gamma}{1+\gamma}\right)\left(\frac{1-r}{2-\gamma}\right)^2$

Table B.2: DECENTRALISED UNION

	R&D	No R&D
R&D	$\left(\frac{1-\gamma}{1+\gamma}\right)\left(\frac{\left(2-\gamma^2\right)(1-r\phi)}{(2-\gamma)\left(4-\gamma-2\gamma^2\right)}\right)^2-k,$ $\left(\frac{1-\gamma}{1+\gamma}\right)\left(\frac{\left(2-\gamma^2\right)(1-r\phi)}{(2-\gamma)\left(4-\gamma-2\gamma^2\right)}\right)^2-k$	$\eta_1-k,\ \eta_2$
No R&D	$\eta_2,\ \eta_1-k$	$\left(\frac{1-\gamma}{1+\gamma}\right)\left(\frac{(1-r)\left(2-\gamma^2\right)}{(2-\gamma)\left(4-\gamma-2\gamma^2\right)}\right)^2,$ $\left(\frac{1-\gamma}{1+\gamma}\right)\left(\frac{(1-r)\left(2-\gamma^2\right)}{(2-\gamma)\left(4-\gamma-2\gamma^2\right)}\right)^2$

where, $\eta_1 = \dfrac{\left(2-\gamma^2\right)^2\left[(1-\gamma)(2+\gamma)\left(4+\gamma-2\gamma^2\right)-r\left(8\phi-\gamma\left(2-\gamma^2+9\gamma\phi-2\gamma^3\phi\right)\right)\right]^2}{\left(1-\gamma^2\right)\left(4-\gamma^2\right)^2\left(16-17\gamma^2+4\gamma^4\right)^2}$

and, $\eta_2 = \dfrac{\left(2-\gamma^2\right)^2\left[(1-\gamma)(2+\gamma)\left(4+\gamma-2\gamma^2\right)-r\left(8-\gamma\left(9\gamma-2\gamma^3+2\phi-\gamma^2\phi\right)\right)\right]^2}{\left(1-\gamma^2\right)\left(4-\gamma^2\right)^2\left(16-17\gamma^2+4\gamma^4\right)^2}$.

Table B.3: CENTRALISED UNION

	R&D	No R&D
R&D	$\frac{1}{4}\left(\frac{1-\gamma}{1+\gamma}\right)\left(\frac{1-r\phi}{2-\gamma}\right)^2-k,$ $\frac{1}{4}\left(\frac{1-\gamma}{1+\gamma}\right)\left(\frac{1-r\phi}{2-\gamma}\right)^2-k$	$\frac{\left[(2+\gamma)(1-\gamma)+r\left(\gamma+\gamma^2\phi-2\phi\right)\right]^2}{4\left(4-\gamma^2\right)^2\left(1-\gamma^2\right)}-k,$ $\frac{\left[(2+\gamma)(1-\gamma)+r\left(\gamma^2+\gamma\phi-2\right)\right]^2}{4\left(4-\gamma^2\right)^2\left(1-\gamma^2\right)}$
No R&D	$\frac{\left[(2+\gamma)(1-\gamma)+r\left(\gamma^2+\gamma\phi-2\right)\right]^2}{4\left(4-\gamma^2\right)^2\left(1-\gamma^2\right)},$ $\frac{\left[(2+\gamma)(1-\gamma)+r\left(\gamma+\gamma^2\phi-2\phi\right)\right]^2}{4\left(4-\gamma^2\right)^2\left(1-\gamma^2\right)}-k$	$\frac{1}{4}\left(\frac{1-\gamma}{1+\gamma}\right)\left(\frac{1-r}{2-\gamma}\right)^2,$ $\frac{1}{4}\left(\frac{1-\gamma}{1+\gamma}\right)\left(\frac{1-r}{2-\gamma}\right)^2$

Appendix C: Proofs of Propositions 1 – 3

(C.1) Proof of Proposition 1:

I have, $k_H^d - k_H^n = -\dfrac{2r\left(2-\gamma^2\right)(1-\phi)\left[(1-r)\gamma\mu_1 + 2\left(3-\gamma^2\right)\left(2-\gamma^2\right)^3\left(4-3\gamma^2\right)(2-r-r\phi)\right]}{(2-\gamma)^2\left(1-\gamma^2\right)(2+\gamma)^2\left(16-17\gamma^2+4\gamma^4\right)^2} < 0$

where, $\mu_1 = \left(224 - 476\gamma^2 + 365\gamma^4 - 119\gamma^6 + 14\gamma^8\right)$. Also, check that

$$k_L^d - k_H^n = \frac{2r\left(2-\gamma^2\right)(1-\phi)\left[(1-\gamma)(2+\gamma)\left(4+\gamma-2\gamma^2\right)\left(48-16\gamma-74\gamma^2+17\gamma^3+37\gamma^4-4\gamma^5-6\gamma^6\right)+r\mu_2\right]}{(2-\gamma)^2\left(1-\gamma^2\right)(2+\gamma)^2\left(4+\gamma-2\gamma^2\right)^2\left(4-\gamma-2\gamma^2\right)^2} < 0$$

where, $\mu_2 = 256\gamma + 496\gamma^2 - 544\gamma^3 - 504\gamma^4 + 417\gamma^5 + 252\gamma^6 - 136\gamma^7 - 62\gamma^8 + 16\gamma^9 + 6\gamma^{10}$

$-192\phi - 32\gamma\phi + 496\gamma^2\phi + 68\gamma^3\phi - 504\gamma^4\phi - 52\gamma^5\phi + 252\gamma^6\phi + 17\gamma^7\phi - 62\gamma^8\phi - 2\gamma^9\phi + 6\gamma^{10}\phi - 192.$

And,

$$k_L^n - k_H^d = \frac{2r\left(2-\gamma^2\right)(1-\phi)\left[(1-\gamma)(2+\gamma)\left(4+\gamma-2\gamma^2\right)\left(48-16\gamma-74\gamma^2+17\gamma^3+37\gamma^4-4\gamma^5-6\gamma^6\right)+r\mu_3\right]}{(2-\gamma)^2\left(1-\gamma^2\right)(2+\gamma)^2\left(16-17\gamma^2+4\gamma^4\right)^2}$$

where, $\mu_3 = -192 - 32\gamma + 496\gamma^2 + 68\gamma^3 - 504\gamma^4 - 52\gamma^5 + 252\gamma^6 + 17\gamma^7 - 62\gamma^8 - 2\gamma^9 + 6\gamma^{10}$

$-192\phi + 256\gamma\phi + 496\gamma^2\phi - 544\gamma^3\phi - 504\gamma^4\phi + 417\gamma^5\phi + 252\gamma^6\phi - 136\gamma^7\phi - 62\gamma^8\phi + 16\gamma^9\phi + 6\gamma^{10}\phi.$

Check that, $k_L^n < k_H^d$ for $r > r_1$ and $k_L^n > k_H^d$ for $r < r_1$ where,

$r_1 = -\dfrac{(1-\gamma)(2+\gamma)\left(4+\gamma-2\gamma^2\right)\left(48-16\gamma-74\gamma^2+17\gamma^3+37\gamma^4-4\gamma^5-6\gamma^6\right)}{\mu_3}.$ Again,

$$k_L^n - k_L^d = \frac{2r\left(2-\gamma^2\right)(1-\phi)\left[(1-\gamma)(2+\gamma)\left(4+\gamma-2\gamma^2\right)\left(48-16\gamma-74\gamma^2+17\gamma^3+37\gamma^4-4\gamma^5-6\gamma^6\right)+r\mu_4\right]}{(2-\gamma)^2\left(1-\gamma^2\right)(2+\gamma)^2\left(16-17\gamma^2+4\gamma^4\right)^2}$$

where,

$\mu_2 = -192 + 496\gamma^2 - 504\gamma^4 + 252\gamma^6 - 62\gamma^8 + 6\gamma^{10} - 192\phi + 224\gamma\phi + 496\gamma^2\phi - 476\gamma^3\phi - 504\gamma^4\phi$

$+365\gamma^5\phi + 252\gamma^6\phi - 119\gamma^7\phi - 62\gamma^8\phi + 14\gamma^9\phi + 6\gamma^{10}\phi.$ See that, $k_L^n < k_L^d$ for $r > r^d$ and $k_L^n > k_L^d$

for $r < r^d$ where, $r^d = \frac{(1-\gamma)(2+\gamma)\left(4+\gamma-2\gamma^2\right)\left(48-16\gamma-74\gamma^2+17\gamma^3+37\gamma^4-4\gamma^5-6\gamma^6\right)}{\mu_4}$.

Straightforward calculations, show that $r_1 > r^d$. Therefore, rewriting the above and using $k_L^n < k_H^n$ and $k_L^d < k_H^d$ from (A.2), I get the following investment orderings:

$$k_L^d < k_H^d < k_L^n < k_H^n \text{ for } 0 < r < r^d \tag{C.i}$$

$$k_H^d < k_L^n < k_L^d < k_H^n \text{ for } r^d < r < r_1 \tag{C.ii}$$

$$k_L^n < k_L^d < k_H^d < k_H^n \text{ for } r_1 < r < 1 \tag{C.iii}$$

Combining (C.i) – (C.iii), I find that (a) the strategic benefit from innovation is higher under no union than under decentralised unions, i.e., $k_L^d < k_L^n$ when $0 < r < r^d$ and the reverse holds true when $r^d < r < 1$. (b) The non-strategic benefit from innovation is strictly higher under no union than under decentralised unions, i.e., $k_H^d < k_H^n$ for $r \in (0,1)$.

(C.2) Proof of Proposition 2:

I have, $k_L^n - k_L^c = \frac{6r\left(2-\gamma^2\right)\left(2-\gamma-\gamma^2\right)(1-\phi)-3r^2\left(2-\gamma^2\right)(1-\phi)\left(2-\gamma^2+\left(2-2\gamma-\gamma^2\right)\phi\right)}{4\left(4-\gamma^2\right)^2\left(1-\gamma^2\right)}$.

Check that, $k_L^n < k_L^c$ for $r > r^c$ and $k_L^n > k_L^c$ for $r < r^c$ where $r^c = \frac{2(1-\gamma)(2+\gamma)}{2-\gamma^2+2\phi-2\gamma\phi-\gamma^2\phi}$. And,

$$k_L^n - k_H^c = \frac{6r\left(2-\gamma^2\right)\left(2-\gamma-\gamma^2\right)(1-\phi)-r^2\left(2-\gamma^2\right)(1-\phi)\left(6(1+\phi)+\gamma(2-3\gamma-8\phi-3\gamma\phi)\right)}{4\left(4-\gamma^2\right)^2\left(1-\gamma^2\right)}.$$

See that, $k_L^n < k_H^c$ for $r > r_2$ and $k_L^n > k_H^c$ for $r < r_2$ where $r_2 = \frac{6(1-\gamma)(2+\gamma)}{6+2\gamma-3\gamma^2+6\phi-8\gamma\phi-3\gamma^2\phi}$.

Straightforward calculations, show that $r^c > r_2$. Therefore, rewriting the above and using $k_L^n < k_H^n$ and $k_L^c < k_H^c$ from (A.2), I get the following investment orderings:

$$k_L^c < k_H^c < k_L^n < k_H^n \text{ for } 0 < r < r_2 \tag{C.iv}$$

$$k_L^c < k_L^n < k_H^c < k_H^n \text{ for } r_2 < r < r^c \tag{C.v}$$

$$k_L^n < k_L^c < k_H^c < k_H^n \text{ for } r^c < r < 1 \tag{C.vi}$$

Combining (C.iv) – (C.vi), I find that (a) the strategic benefit from innovation is higher under no union than under a centralised union, i.e., $k_L^c < k_L^n$ when $0 < r < r^c$ and the reverse holds true when $r^c < r < 1$. (b) the non-strategic benefit from innovation is always higher under no union than under a centralised union, i.e., $k_H^c < k_H^n$ for $r \in (0,1)$.

(C.3) Proof of Proposition 3:

I have, $k_L^c - k_L^d = -\dfrac{r\gamma(2-\gamma^2)(1-\phi)\left[\gamma(2-\gamma^2)(35\gamma^2-8\gamma^4-32)(2-r-r\phi)+\theta_1\right]}{4(2-\gamma)^2(1-\gamma^2)(2+\gamma)^2(16-17\gamma^2+4\gamma^4)^2} < 0$ and,

$$k_L^c - k_H^d = -\frac{r\gamma(2-\gamma^2)(1-\phi)\left[\theta_2+\theta_3+2\gamma^4(209+208r-417r\phi)\right]}{4(2-\gamma)^2(1-\gamma^2)(2+\gamma)^2(16-17\gamma^2+4\gamma^4)^2} < 0$$

where,

$\theta_1 = 2(128-272\gamma^2+209\gamma^4-68\gamma^6+8\gamma^8)(1-r\phi)$, $\theta_2 = 8(32-68\gamma^2-17\gamma^6+2\gamma^8)(1+r-2r\phi)$, and $\theta_3 = \gamma(2-\gamma^2)(32-35\gamma^2+8\gamma^4)(2-r-r\phi)$. I also get that,

$$k_H^d - k_H^c = -\frac{r\gamma(2-\gamma^2)(1-\phi)(-256+128\gamma+544\gamma^2-204\gamma^3-418\gamma^4+102\gamma^5+136\gamma^6-16\gamma^7-16\gamma^8+r\theta_4)}{4(2-\gamma)^2(1-\gamma^2)(2+\gamma)^2(16-17\gamma^2+4\gamma^4)^2}$$

where,

$$\theta_4 = 256-64\gamma-544\gamma^2+102\gamma^3+418\gamma^4-51\gamma^5-136\gamma^6+8\gamma^7+16\gamma^8-64\gamma\phi+102\gamma^3\phi-51\gamma^5\phi+8\gamma^7\phi.$$

Check that, $k_H^d < k_H^c$ for $r > r^*$ and $k_H^d > k_H^c$ for $r < r^*$ where

$$r^* = \frac{2(1-\gamma)(2+\gamma)(4+\gamma-2\gamma^2)(16-4\gamma-17\gamma^2+2\gamma^3+4\gamma^4)}{256-64\gamma-544\gamma^2+102\gamma^3+418\gamma^4-51\gamma^5-136\gamma^6+8\gamma^7+16\gamma^8-64\gamma\phi+102\gamma^3\phi-51\gamma^5\phi+8\gamma^7\phi}.$$

Also, I find that

$$k_L^d - k_H^c = \frac{r\gamma\left(2-\gamma^2\right)(1-\phi)\left(256-128\gamma-544\gamma^2+204\gamma^3+418\gamma^4-102\gamma^5-136\gamma^6+16\gamma^7+16\gamma^8+r\theta_5\right)}{4(2-\gamma)^2\left(1-\gamma^2\right)(2+\gamma)^2\left(16-17\gamma^2+4\gamma^4\right)^2}$$

where,

$\theta_5 = -512+64\gamma+1088\gamma^2-102\gamma^3-834\gamma^4+51\gamma^5+272\gamma^6-8\gamma^7-32\gamma^8+256\phi+64\gamma\phi-544\gamma^2\phi-102\gamma^3\phi$ $+416\gamma^4\phi+51\gamma^5\phi-136\gamma^6\phi-8\gamma^7\phi+16\gamma^8\phi$. See that, $k_L^d < k_H^c$ for $r > r_3$ and $k_L^d > k_H^c$ for $r < r_3$ where, $r_3 = \frac{2(1-\gamma)(2+\gamma)\left(2\gamma^2-\gamma-4\right)\left(16-4\gamma-17\gamma^2+2\gamma^3+4\gamma^4\right)}{\theta_6}$ and $\theta_6 = 64\gamma+1088\gamma^2-102\gamma^3$ $-834\gamma^4+51\gamma^5+272\gamma^6-8\gamma^7-32\gamma^8+256\phi+64\gamma\phi-544\gamma^2\phi-102\gamma^3\phi+416\gamma^4\phi+51\gamma^5\phi-136\gamma^6\phi$ $-8\gamma^7\phi+16\gamma^8\phi-512$. Straightforward calculations, show that $r^* > r_3$. Therefore, rewriting the above and using $k_L^d < k_H^d$ and $k_L^c < k_H^c$ from (A.2), I get the following investment orderings:

$$k_L^c < k_H^c < k_L^d < k_H^d \text{ for } 0 < r < r_3 \quad \text{(C.vii)}$$

$$k_L^c < k_L^d < k_H^c < k_H^d \text{ for } r_3 < r < r^* \quad \text{(C.viii)}$$

$$k_L^c < k_L^d < k_H^d < k_H^c \text{ for } r^* < r < 1 \quad \text{(C.ix)}$$

Combining (C.vii) – (C.ix), I find that (a) the strategic benefit from innovation is always higher under decentralised unions than under a centralised union, i.e., $k_L^c < k_L^d$, and (b) the non-strategic benefit from innovation is higher under a centralised unions than under decentralised union, i.e., $k_H^d < k_H^c$ when $r^* < r < 1$ and the reverse holds true when $0 < r < r^*$.

References

Basak, D. and A. Mukherjee, 2018, ‘Labour unionisation structure and product innovation’, *International Review of Economics and Finance*, 55: 98-110.

Bughin, J and S. Vannini, 1995, ‘Strategic direct investment under unionised oligopoly’, *International Journal of Industrial organisation*, 13: 127-45.

Calabuig, V. and M. Gonzalez-Maestre, 2002, ‘Union structure and incentives for innovation’, *European Journal of Political Economy*, 18: 177-92.

Calmfors, L. and J. Drifill, 1988, ‘Centralisation and wage bargaining’, *Economic Policy*, 6: 13-61.

Davidson, C., 1988, ‘Multiunit Bargaining in oligopolistic industries’, *Journal of labour Economics*, 6: 397-422.

Deneckere, R. and C. Davidson, 1985, ‘Incentives to form coalitions with Bertrand competition’, *Rand Journal of Economics*, 16: 473-86.

Ellguth, P., H. D. Gerner, and J. Stegmaier, 2014, ‘Wage effects of works councils and opening clauses: The German case’, *Economic and Industrial Democracy*, 35: 95-113.

Flanagan, R. J., 1999, ‘Macroeconomic performance and collective bargaining: an international perspective’, *Journal of Economic Literature*, 37: 1150-75.

Goeddeke, A., 2010, ‘Strategic profit sharing in a unionized oligopoly’, Working Paper, Ruhn-University of Bochum.

Haucap, J. and C. Wey, 2004, ‘Unionisation structures and innovation incentives’, *Economic Journal,* 114: C149-65.

Horn, H. and A. Wolinsky, 1988, ‘Bilateral monopolies and incentive for merger’, *Rand Journal of Economics,* 19: 408-19.

Hübler, O. and W. Meyer, 2000, ‘Industrial relations and the wage differentials between skilled and unskilled blue-collar workers within establishments: An empirical analysis with data of manufacturing firms. IZA Discussion paper series no. 176.

Layard, R., S. Nickell, and R. Jackman, 1991, ‘Unemployment, macroeconomic performance and the labour market’, Oxford: Oxford University Press.

López, M. C. and R. A. Naylor, 2004, ‘The Cournot-Bertrand profit differential: a reversal result in a differentiated duopoly with wage bargaining’, *European Economic Review*, 48: 681-96.

Manasakis, C. and E. Petrakis, 2009, ‘Union structure and firms' incentives for cooperative R&D investments’, *Canadian Journal of Economics*, 42: 665-93.

Milgrom P. and J. Roberts, 1992, Economics, Organization and Management, Prentice-Hall International.

Moene, K. O. and M. Wallerstein, 1997, ‘Pay inequality’, *Journal of Labour Economics*, 15: 403-30.

Mukherjee, A. and E. Pennings, 2011, ‘Unionisation structure, licensing and innovation’, *International Journal of Industrial organisation*, 29: 232-41.

Nickell, S., 1997, ‘Unemployment and labour market rigidities: Europe versus North America’, *Journal of Economic Perspectives*, 11: 55-74.

OECD, 1996, The OECD jobs study: implementing the strategy, OECD, Paris.

OECD, 2004, Trade and migration: building bridges for global labour mobility, OECD, Paris.

Ogawa, H., Y. Sato and T. Tamai, 2016, ‘Who gains from capital market integration? Tax competition between unionized and non-unionized countries’, *Canadian Journal of Economics*, 49: 76-110.

Oswald, A. J., 1993, ‘Efficient contracts are on the labour demand curve: Theory and facts’, *Labour Economics*, 1, 85--113.

Roy Chowdhury, P., 2005, 'Patents and R&D: the tournament effect', *Economics Letters*, 89: 120-26.

Salant, S., S. Switzer and R. Reynolds, 1983, 'Losses from horizontal merger: the effects of an exogenous change in industry structure on Cournot-Nash equilibrium', *Quarterly Journal of Economics*, 98: 185-99.

Siebert, H., 1997, 'Labour market rigidities: at the root of unemployment in Europe', *Journal of Economic Perspectives*, 11: 37-54.

Ulph, A. and D. Ulph, 1994, 'Labour markets, bargaining and innovation', *European Economic Review*, 42: 931-39.

Ulph, A. and D. Ulph, 2001, 'Strategic innovation with complete and incomplete labour market contracts', *Scandinavian Journal of Economics*, 103: 265-82.

Visser, J. (2006, January), 'Union membership statistics in 24 countries', *Monthly Labor Review*, 38-49.

Wallerstein, M., 1999, 'Wage-setting institutions and pay inequality in advanced industrial societies', *American Journal of Political Science*, 43: 649-80.

Williamson, O., 1975, 'Markets and hierarchies: Analysis and antitrust implications', The Free Press.