Unionisation structure and product innovation*

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Abstract

This paper considers the effects of different labour unionisation structure (viz., decentralised and centralised unions) on product innovation. Although the presence of labour unions reduces the incentive for product innovation compared to the situation with no labour union (or if the unions have no bargaining power in wage determination), the effects of different labour unionisation structure on innovation are not so straightforward. In the case of symmetric product differentiation, the incentive for innovation is higher under decentralised unions. However, the incentive for innovation can be higher under a centralised union than under decentralised unions in the presence of asymmetric product differentiation. Our paper provides a new perspective to the literature by focusing on product innovation.

Key Words: Centralised union; Decentralised union; Product innovation

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1 Introduction

Labour unions differ substantially between countries with respect to the degree of wage setting centralisation (Calmfors and Driffill, 1988, Moene and Wallerstein, 1997, Flanagan, 1999 and Wallerstein, 1999). Decentralised wage setting is often contrasted with centralised wage setting. Under a decentralised wage setting, wages are set between employers and firm-specific unions, while under a centralised wage setting, an industry-wide union negotiates wages with all firms (Haucap and Wey, 2004). 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).

Given the diversity of unionised labour market, the purpose of this paper is to show the effects of different labour unionisation structure on the firms' incentives for *product innovation*. Considering the case of no labour union as our benchmark, we compare the incentives for innovation under decentralised unions and under a centralised union.

In what follows, we develop a simple model of product innovation in Section 2. In a duopoly market structure, we assume that each firm has an existing product and may innovate a new product. We begin our analysis with symmetrically differentiated products. We show that the absence of labour union provides higher incentive for product innovation compared to the situations with labour unions, irrespective of the labour unionisation structure. However, a comparison between a centralised union and decentralised unions reveals that the latter unionisation structure provides higher incentive for innovation compared to the former unionisation structure.

Although symmetric product differentiation can be a useful starting point, this may be a strong assumption to consider, and more particularly, if this assumption is important for the result. We show in Section 3 that the incentive for innovation can be higher under a centralised union than under decentralised unions in the presence of asymmetric product differentiation, although the presence of labour union reduces the incentive for innovation compared to no labour union, irrespective of the unionisation structure. It would be useful to consider a general framework capturing all possible degree of product differentiation among the products. Unfortunately, we cannot do it due to analytical tractability. However, we consider a particular type of asymmetric product differentiation in Section 3. Considering perfectly substitutable existing products,[1] we show that the incentive for product

[1] This structure is certainly justifiable. As an example, we may visualise the existing products as simple first generation mobile phones, while the new products are more advanced third generation mobile phones with added facilities such as camera and web-browsing facilities. The first generation mobile phones, which are mainly used for calling, are more likely to be perfect substitutes,while the third generation mobile phones with added facilities may be more likely to be imperfect substitutes due to their different screen size and resolution, different pixels of the cameras, and differet layouts of the keyboards. Although the first generation mobile phones can also be imperfect substitutes due to their looks and the bettery lives, it may be more natural to consider the third generation mobile phones are more imperfect substitutes that the first generation mobile phones. As a simplification, we consider the first generation mobile phones as perfect substitutes.

innovation may be higher under a centralised union than under decentralised unions. The incentive for innovation is higher under decentralised unions if the existing and the new products are sufficiently differentiated so that the existing products do not face much competition from the new products. If the existing and the new products are not very much differentiated, the incentive for innovation may be higher under a centralised union. Hence, we can say from the results of Sections 2 and 3 that if the degree of product differentiation among the new products are sufficiently larger than the degree of product differentiation among the existing products, the incentive for product innovation may be higher under a centralised union; otherwise, the incentive for product innovation is higher under decentralised unions.

The main contribution of this paper lies on its focus on product innovation. The existing literature showing the effects of labour union on innovation has focused on *process innovation.*[2] While the earlier works have shown the impacts of union bargaining power,[3] more recent contributions show the effects of different unionisation structure (Calabuig and Gonzalez-Maestre, 2002, Haucap and Wey, 2004, Manasakis and Petrakis, 2009 and Mukherjee and Pennings, 2011). Investment in process innovation is certainly a major part of the firms' R&D expenditures. However, the firms in today's world also allocate significant amount of their R&D budget towards product innovation. For example, as mentioned in Imai (1992), the Japanese firms allocate R&D budget in process innovation relative to product at a ratio of 60:40. It is argued in Mansfield (1988) that American firms have traditionally spent more in product innovation than Japanese firms. Although the industrial organisation literature has started to uncover the effects of product innovation in other contexts (Lin and Saggi, 2002, Rosenkranz, 2003, Braun, 2008 and Lambertini and Mantovani, 2009 and 2010, to name a few), the effects of a vertical structure is yet to be analysed.[4] This paper is a step to fill this gap. It is also worth mentioning that, in contrast to the above-mentioned papers on product innovation, where an increase in the degree of product differentiation is considered as product innovation, we consider new product creation under product innovation.

It is now worth relating our paper to the existing literature showing the effects of the labour unionisation structure on process innovation. In a model with R&D competition, Calabuig and Gonzalez-Maestre (2002) show that the incentive for innovation is higher under decentralised unions for non-drastic innovations; however, the incentive for innovation can be higher under a centralised union in the case of a

[2] A notable exception is Lambertini and Mantovani (2009), which consider product innovation creating new products. However, they analyse a market with a monopolist with no labor union. Hence, they ignore strategic interactions in both the product market and in the input market, which we consider here.

[3] 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.

[4] Although we consider labour union as the upstream agent, it is worth mentioning that our results will hold if, instead of labour unions, we consider the upstream agents as profit maximising input suppliers. With this interpretation, we can consider the decetralised structure as a situation with firm-specific input suppliers, and the centralised structure as a situation with either an industry-wide input supplier or collusion between different input suppliers.

drastic innovation. In a patent race model, Haucap and Wey (2004) show that if the centralised union charges a uniform wage to all firms, the incentive for innovation is higher under a centralised union; however, in the case of wage discrimination by the centralised union, the incentive for innovation is higher under decentralised unions. Manasakis and Petrakis (2009) show that, under non-cooperative R&D, the incentive for innovation is higher under decentralised unions if knowledge spillovers are high; however, the incentive for innovation is always higher under decentralised unions under cooperative R&D. Considering an innovating firm and a non-innovating firm, Mukherjee and Pennings (2011) show the implications of technology licensing ex-post innovation. They show that if the unions' preferences for wage (compared to employment) are high, the innovator's incentive for innovation is higher under a centralised union irrespective of licensing ex-post innovation; however, if the unions' preferences for employment are high, the benefit from licensing may help to create higher incentive for innovation under decentralised unions.

The reasons behind the above-mentioned results are related to different types of constraints imposed by different unionisation structure affecting the hold-up problem. Haucap and Wey (2004) show that the uniformity rule under a centralised union is more effective in constraining the unions' hold-up potential and leads to higher incentives for innovation under a centralised union; however, if the centralised union discriminates wage, it helps the union to exploit its hold-up problem at the maximum level, 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. 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. 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 under decentralised unions by reducing the negative effects of the hold-up problem under decentralised unions.

Product innovation (compared to process innovation) creates different wage effects in our analysis. While process innovation creates a direct negative effect on labour demand by reducing the labour content in the product process, product innovation in our analysis creates an opposite effect. If a firm invents a new product, its labour demand increases due to an increase in the number of products produced by the innovator. Whether this wage effect increases the hold-up problem under decentralised unions or under a centralised union depends on the degree of product differentiation between the existing and the new products. Thus, in contrast to the previous papers on process innovation, the unionisation structures may have ambiguous effects on product innovation even if the centralised union charges a uniform wage, the innovations are non-drastic and there is neither knowledge spillover nor technology licensing.

There is no doubt that the level of wage bargaining, the bargaining agenda and

the bargaining power distribution between firms and the unions are among the important determinants of innovation (Bassanini and Ernst, 2002 and Hirsch, 2004), yet there is controversy about their exact effects on firms' performance, innovation and labour productivity (see, Flanagan, 1999, for a survey on this topic). The existing empirical works showing the effects of union on innovation mainly show the effects of union power on the incentives for innovation. Freeman and Medoff (1984) show that the effect of unionisation is ambiguous on innovation. Using COMPUSTAT data, Bronas and Deere (1993) show that there is a significant negative relationship between firm-specific unionisation rate and innovation. Using mainly aggregative industry level data, Ulph and Ulph (1989) find a negative relation for the high-tech industries in England, while Addison and Wagner (1994) find a positive but insignificant relation. It is documented in Menezes-Filho et al. (1998) that most U.S. studies show a negative effect between union power and innovation, while the evidence from some European studies is less compelling.[5] Menezes-Filho and Van Reenen (2003) also show strong and negative effects of unions on innovation in North America, while that is generally not the case in the UK.

Although the existing empirical works mainly show the effects of stronger unions rather than the effects of different unionisation structure, the implied hold-up problems under different union powers may have similar implications for different hold-up problems under different unionisation structure. In line with the empirical evidence, our results show that the effects of different hold-up problems under different unionisation structure are not straightforward in determining their effects on product innovation. Our paper along with the previous theoretical papers on process innovation suggests that the relative effects of different unionisation structure on innovation depend significantly on the type of innovation (process or product). Hence, more empirical works are needed to uncover the effects of the unionisation structure on innovation. Our paper provides testable hypotheses for future empirical works.

The remainder of the paper is organized as follows. In section 2, we describe the model and derives the results for symmetrically differentiated products. Section 3 show the implications of asymmetric product differentiation. Section 4 concludes.

2 The model with symmetric product differentiation

We consider an economy where two firms, indexed by $k = 1, 2$, compete like Cournot duopolists. We assume that initially firm 1 and firm 2 produce goods g and h respectively. The goods are assumed to be horizontally differentiated. However, each firm may innovate a new product by investing $I > 0$. We denote the new products of firms 1 and 2 by y and z respectively.

We assume that labour, L_i, is the only factor of production where i indexes for goods produced in the economy. The total labour demand per firm is $L_k = \sum L_i$. We assume that both firms need one worker to produce one unit of output, irrespective of the products produced. This allows us to show the effects of product

[5] In the European Union centralised unionisation is generally more common, while decentralised unionisation is more relevant in the U.S. See Iversen (1998) for an index of centralisation of wage bargaining in different countries.

innovation by deliberately eliminating the differences in labour productivities for different products. The wages of the workers are endogenous and are determined by the (centralised and decentralised) labour unions. In order to capture the maximum effect of labour union, following Calabuig and Gonzalez-Maestre (2002) and Haucap and Way (2004), we assume that the labour unions have full bargaining power in wage determination.

We assume that the inverse demand function for the ith product is

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

where $i, j = \{g, h, y, z\}$, $i \neq j$, P_i and q_i are price and output of product i and the parameter $\gamma \in [0, 1]$ measures the degree of product differentiation between the products. If $\gamma = 1$, the products are perfect substitutes and if $\gamma = 0$, the products are isolated. Since we consider products y and z to be different from products g and h, we will concentrate on $\gamma \in [0, 1)$.

We consider the following game structure. Given the unionisation structure, at stage 1, the firms decide simultaneously whether or not to innovate the new product. At stage 2, the wages are determined by the labour unions. At stage 3, the firms compete like Cournot duopolists and the profits are realised. We solve the game through backward induction.

2.1 The equilibrium outputs

We start by considering the output stage. At this stage, the firms consider the number of products and the wages given.

First, consider the case where neither firm innovates the new product. If firm 1 and firm 2 produce good g and good h respectively, the respective outputs are:

$$q_g^* = \left[\frac{(2-\gamma)\, a - 2w_1 + \gamma w_2}{4 - \gamma^2}\right] \tag{2}$$

$$q_h^* = \left[\frac{(2-\gamma)\, a + \gamma w_1 - 2w_2}{4 - \gamma^2}\right]. \tag{3}$$

Now consider the case where only firm 1 innovates the new product. In this situation, firm 1 produces g and y and firm 2 produces h. We get the resulting outputs as:

$$\widehat{q}_g = \widehat{q}_y = \left[\frac{(2-\gamma)\, a - 2w_1 + \gamma w_2}{2\,(2 + 2\gamma - \gamma^2)}\right] \tag{4}$$

$$\widehat{q}_h = \left[\frac{a + \gamma w_1 - (1+\gamma)\, w_2}{(2 + 2\gamma - \gamma^2)}\right]. \tag{5}$$

Similarly, if only firm 2 innovates the new product, firm 1 produces g and firm 2 produces h and z. We get the resulting outputs as:

$$\widetilde{q}_g = \left[\frac{a + \gamma w_1 - (1+\gamma)\, w_2}{(2 + 2\gamma - \gamma^2)}\right] \tag{6}$$

$$\widetilde{q}_h = \widetilde{q}_z = \left[\frac{(2-\gamma)\, a - 2w_1 + \gamma w_2}{2\,(2 + 2\gamma - \gamma^2)}\right]. \tag{7}$$

Finally, consider the case where both firms innovate new products. In this situation, firm 1 produces g and y and firm 2 produces h and z. We get the resulting outputs as:

$$\overline{q}_g = \overline{q}_y = \left[\frac{a-(1+\gamma)\,w_1+\gamma w_2}{2\,(1+2\gamma)}\right] \tag{8}$$

$$\overline{q}_h = \overline{q}_z = \left[\frac{a+\gamma w_1-(1+\gamma)\,w_2}{2\,(1+2\gamma)}\right]. \tag{9}$$

2.2 Wages and profits

Now we are in position to determine the equilibrium wages and profits of the firms conditional on the innovation strategies.

2.2.1 No Union

First, consider the benchmark case of no union, where the firms pay the reservation wages to the workers, i.e., $w_1 = w_2 = c$. Alternatively, we can consider this as a situation where the firms have full bargaining power in wage determination.

Straightforward calculations show that, if neither firm innovates, the equilibrium profits are:

$$\pi_1^* = \pi_2^* = \left[\left(\frac{a-c}{2+\gamma}\right)^2\right]. \tag{10}$$

If only firm 1 innovates, the equilibrium profits are:

$$\widehat{\pi}_1 = \left[\frac{1}{2}\left(\frac{a-c}{2+2\gamma-\gamma^2}\right)^2\left(2+\gamma-\gamma^2\right)(2-\gamma)-I\right] \tag{11}$$

$$\widehat{\pi}_2 = \left[\left(\frac{a-c}{2+2\gamma-\gamma^2}\right)^2\right]. \tag{12}$$

If only firm 2 innovates, the equilibrium profits are:

$$\widetilde{\pi}_1 = \left[\left(\frac{a-c}{2+2\gamma-\gamma^2}\right)^2\right] \tag{13}$$

$$\widetilde{\pi}_2 = \left[\frac{1}{2}\left(\frac{a-c}{2+2\gamma-\gamma^2}\right)^2\left(2+\gamma-\gamma^2\right)(2-\gamma)-I\right]. \tag{14}$$

Finally, if both firms innovate, the equilibrium profits are:

$$\overline{\pi}_1 = \overline{\pi}_2 = \left[\frac{1}{2}\left(\frac{a-c}{1+2\gamma}\right)^2(1+\gamma)-I\right]. \tag{15}$$

Table 2.1 summarises the profits of the firms under no union, conditional on the innovation strategies.

Table 2.1

Firm 2 $\rightarrow$ Firm 1 $\downarrow$	R&D	No R&D
R&D	$\frac{(a-c)^2(1+\gamma)}{2(1+2\gamma)^2} - I$, $\frac{(a-c)^2(1+\gamma)}{2(1+2\gamma)^2} - I$	$\frac{(a-c)^2\left(2+\gamma-\gamma^2\right)(2-\gamma)}{2(2+2\gamma-\gamma^2)^2} - I$, $\frac{(a-c)^2}{(2+2\gamma-\gamma^2)^2}$
No R&D	$\frac{(a-c)^2}{(2+2\gamma-\gamma^2)^2}$, $\frac{(a-c)^2\left(2+\gamma-\gamma^2\right)(2-\gamma)}{2(2+2\gamma-\gamma^2)^2} - I$	$\frac{(a-c)^2}{(2+\gamma)^2}$, $\frac{(a-c)^2}{(2+\gamma)^2}$

The comparison of the above profits gives the following result immediately.

Proposition 1 *Assume that there is no labour union (or the firms have full bargaining power in wage determination).*

(a) Both firms innovate if $I < I_L$*, where* $I_L = \frac{1}{2}(a-c)^2\left[\frac{1+\gamma}{(1+2\gamma)^2} - \frac{2}{(2+2\gamma-\gamma^2)^2}\right]$.

(b) Neither firm innovates if $I_H < I$*, where* $I_H = \frac{1}{2}(a-c)^2\left[\frac{(2-\gamma)\left(2+\gamma-\gamma^2\right)}{(2+2\gamma-\gamma^2)^2} - \frac{2}{(2+\gamma)^2}\right]$.

(c) Only one firm innovates if $I_L < I < I_H$.

If $I < I_L$, both firms innovate, and we denote this equilibrium by (RD,RD). If $I > I_H$, neither firm innovates, and we denote this equilibrium by (No RD,No RD). If $I_L < I < I_H$, only one firm innovates, and we denote these equilibria by (RD, No RD) and (No RD, RD).[6]

We can describe the equilibrium R&D strategy of the firms in terms of non-strategic and strategic benefits from innovation (Roy Chowdhury, 2005). A firm's non-strategic (strategic) benefit from innovation is given by its payoff from innovation, net of its payoff from no innovation, when the competitor firm does not innovate (innovates).

Since the firms are symmetric, without any loss of generality, consider the case of firm 1. If firm 2 does not innovate, firm 1 innovates for $\frac{(2-\gamma)\left(2+\gamma-\gamma^2\right)(a-c)^2}{2(2+2\gamma-\gamma^2)^2} - \frac{(a-c)^2}{(2+\gamma)^2} \equiv I_H > I$, i.e., if firm 1's gross non-strategic benefit from innovation, which is given by I_H, is greater than the cost of innovation. However, if firm 2 innovates, firm 1 innovates for $\frac{(1+\gamma)(a-c)^2}{2(1+2\gamma)^2} - \frac{(a-c)^2}{(2+2\gamma-\gamma^2)^2} \equiv I_L > I$, i.e., if firm 1's gross strategic benefit from innovation, which is given by I_L, is greater than the cost of innovation.

The above result shows that the non-strategic benefit from innovation is higher than the strategic benefit from innovation. The intuition for this is as follows. Innovation has two effects on the profitability of the innovator. On the one hand, it tends to increase the profit of the innovator by allowing it to produce more products. On the other hand, the cost of innovation tends to reduce the profit of the innovator. If the cost of innovation is small, the first effect dominates the second effect, and both firms find innovation profitable. As the cost of innovation increases, it reduces a firm's incentive for innovation, given that the other firm innovates, i.e., the strategic

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

benefit from innovation reduces. Now, consider that the cost of innovation is such that it is equal to the strategic benefit from innovation. If the cost of innovation increases further, it creates a firm's strategic benefit from innovation lower than the cost of innovation, thus encouraging only one firm to innovate in this situation. As the cost of innovation increases further, it reduces a firm's non-strategic benefit from innovation. If the cost of innovation is very high, a firm's non-strategic benefit from innovation becomes lower than the cost of innovation, and no firm innovates in this situation.

2.2.2 A centralised union

We now consider the situation where the wages are set by a centralised labour union. Under the centralised wage bargaining, the union may set either a uniform wage or discriminatory wages for the workers. The industry-wide union maximises the utility function $U = (w - c)(L_1 + L_2)$ with respect to the wage, w, if it charges a uniform wage, and it maximises the utility function $U_k = \sum(w_k - c)L_k$, $k = 1, 2$, with respect to the wage, w_k, if it charges discriminatory wages across firms.

We get that the equilibrium wages are $w^c = \frac{1}{2}(a + c)$, irrespective of the innovation strategies of the firms and whether or not the union charges a uniform wage or discriminatory wages. Hence, the innovation strategies of the firms do not affect the equilibrium wage charged by the centralised union. The reason for this result follows from Dhillon and Petrakis (2002), which show that, under a centralised union, the wage rate is always independent of the market features such as the number of firms, the intensity of competition and the type of competition as long as the equilibrium outputs and the profits are log-linear in wage and the market features.

Although the wages do not depend on the number of products, the equilibrium profits do. If neither firm innovates, the equilibrium profits are**:**

$$\pi_1^{c^*} = \pi_2^{c^*} = \left[\frac{1}{4}\left(\frac{a-c}{2+\gamma}\right)^2\right]. \tag{16}$$

If only firm 1 innovates, the equilibrium profits are:

$$\widehat{\pi}_1^{c^*} = \left[\frac{1}{8}\left(\frac{a-c}{2+2\gamma-\gamma^2}\right)^2\left(2+\gamma-\gamma^2\right)(2-\gamma) - I\right] \tag{17}$$

$$\widehat{\pi}_2^{c^*} = \left[\frac{1}{4}\left(\frac{a-c}{2+2\gamma-\gamma^2}\right)^2\right]. \tag{18}$$

If only firm 2 innovates, the equilibrium profits are:

$$\widetilde{\pi}_1^{c^*} = \left[\frac{1}{4}\left(\frac{a-c}{2+2\gamma-\gamma^2}\right)^2\right] \tag{19}$$

$$\widetilde{\pi}_2^{c^*} = \left[\frac{1}{8}\left(\frac{a-c}{2+2\gamma-\gamma^2}\right)^2\left(2+\gamma-\gamma^2\right)(2-\gamma) - I\right]. \tag{20}$$

If both firms innovate, the equilibrium profits are:

$$\overline{\pi}_1^{c^*} = \overline{\pi}_2^{c^*} = \left[\frac{1}{8}\left(\frac{a-c}{1+2\gamma}\right)^2(1+\gamma) - I\right]. \tag{21}$$

The following table summarises the profits of the firms under a centralised union conditional on the innovation strategies.

Table 2.2

Firm 2 $\rightarrow$ Firm 1 $\downarrow$	R&D	No R&D
R&D	$\frac{(a-c)^2(1+\gamma)}{8(1+2\gamma)^2} - I$, $\frac{(a-c)^2(1+\gamma)}{8(1+2\gamma)^2} - I$	$\frac{(a-c)^2(2+\gamma-\gamma^2)(2-\gamma)}{8(2+2\gamma-\gamma^2)^2} - I$, $\frac{(a-c)^2}{4(2+2\gamma-\gamma^2)^2}$
No R&D	$\frac{(a-c)^2}{4(2+2\gamma-\gamma^2)^2}$, $\frac{(a-c)^2(2+\gamma-\gamma^2)(2-\gamma)}{8(2+2\gamma-\gamma^2)^2} - I$	$\frac{(a-c)^2}{4(2+\gamma)^2}$, $\frac{(a-c)^2}{4(2+\gamma)^2}$

The comparison of the above profits gives the following result immediately.

Proposition 2 *Assume that there is a centralised labour union.*

(a) Both the firms innovate if $I < I_L^c$, *where* $I_L^c = \frac{1}{8}(a-c)^2\left[\frac{1+\gamma}{(1+2\gamma)^2} - \frac{2}{(2+2\gamma-\gamma^2)^2}\right]$.

(b) Neither firm innovates if $I_H^c < I$, *where* $I_H^c = \frac{1}{8}(a-c)^2\left[\frac{(2-\gamma)(2+\gamma-\gamma^2)}{(2+2\gamma-\gamma^2)^2} - \frac{2}{(2+\gamma)^2}\right]$.

(c) Only one firm innovates if $I_L^c < I < I_H^c$.

I_H^c and I_L^c show a firm's gross non-strategic and gross strategic benefits from innovation respectively. Like the case of no union, the wages under a centralised union are independent of the innovation strategies of the firms, and the intuition for the above result is similar to that of Proposition 1.

2.2.3 Decentralised unions

Now consider the third scenario where the wages are set by the decentralised unions. We will see that, unlike no union and a centralised union, the innovation strategies of the firms affect the wages in this situation, thus creating further effects on the incentive for product innovation.

If neither firm innovates, the wages and the profits are:

$$w_1^{d^*} = w_2^{d^*} = \left[\frac{a(2-\gamma)+2c}{4-\gamma}\right] \tag{22}$$

$$\pi_1^{d^*} = \pi_2^{d^*} = \left[\frac{2(a-c)}{(2+\gamma)(4-\gamma)}\right]^2. \tag{23}$$

If only firm 1 innovates, the wages and the profits are:

$$\widehat{w}_1^d = \left[\frac{a\left(4+3\gamma-2\gamma^2\right)+c\left(4+5\gamma+\gamma^2\right)}{8+8\gamma-\gamma^2}\right] \tag{24}$$

$$\widehat{w}_2^d = \left[\frac{a\left(4+2\gamma-\gamma^2\right)+2c\left(2+3\gamma\right)}{8+8\gamma-\gamma^2}\right] \tag{25}$$

$$\widehat{\pi}_1^d = \left[2\left(\frac{(a-c)\left(4+3\gamma-2\gamma^2\right)}{\left(2+2\gamma-\gamma^2\right)\left(8+8\gamma-\gamma^2\right)}\right)^2(1+\gamma)-I\right] \tag{26}$$

$$\widehat{\pi}_2^d = \left[\left(\frac{(a-c)\left(1+\gamma\right)\left(4+2\gamma-\gamma^2\right)}{\left(2+2\gamma-\gamma^2\right)\left(8+8\gamma-\gamma^2\right)}\right)^2\right]. \tag{27}$$

If only firm 2 innovates, the wages and the profits are:

$$\widetilde{w}_1^d = \left[\frac{a\left(4+2\gamma-\gamma^2\right)+2c\left(2+3\gamma\right)}{8+8\gamma-\gamma^2}\right] \tag{28}$$

$$\widetilde{w}_2^d = \left[\frac{a\left(4+3\gamma-2\gamma^2\right)+c\left(4+5\gamma+\gamma^2\right)}{8+8\gamma-\gamma^2}\right] \tag{29}$$

$$\widetilde{\pi}_1^d = \left[\left(\frac{(a-c)\left(1+\gamma\right)\left(4+2\gamma-\gamma^2\right)}{\left(2+2\gamma-\gamma^2\right)\left(8+8\gamma-\gamma^2\right)}\right)^2\right] \tag{30}$$

$$\widetilde{\pi}_2^d = \left[2\left(\frac{(a-c)\left(4+3\gamma-2\gamma^2\right)}{\left(2+2\gamma-\gamma^2\right)\left(8+8\gamma-\gamma^2\right)}\right)^2(1+\gamma)-I\right]. \tag{31}$$

Finally, if both firms innovate, the wages and the profits are:

$$\overline{w}_1^d = \overline{w}_2^d = \left[\frac{a+\left(1+\gamma\right)c}{2+\gamma}\right] \tag{32}$$

$$\overline{\pi}_1^d = \overline{\pi}_2^d = \left[\frac{1}{2}\left(1+\gamma\right)\left(\frac{(a-c)\left(1+\gamma\right)}{\left(2+\gamma\right)\left(1+2\gamma\right)}\right)^2-I\right]. \tag{33}$$

The following table summarises the profits of the firms under decentralised unions conditional on the innovation strategies.

Table 2.3

Firm 2 $\rightarrow$ Firm 1 $\downarrow$	R&D	No R&D
R&D	$\frac{(a-c)^2(1+\gamma)^3}{2(2+\gamma)^2(1+2\gamma)^2}-I$, $\frac{(a-c)^2(1+\gamma)^3}{2(2+\gamma)^2(1+2\gamma)^2}-I$	$\frac{(a-c)^2\left(4+3\gamma-2\gamma^2\right)^2(1+\gamma)}{2(2+2\gamma-\gamma^2)^2(8+8\gamma-\gamma^2)^2}-I$, $\frac{(a-c)^2(1+\gamma)^2\left(4+2\gamma-\gamma^2\right)^2}{(2+2\gamma-\gamma^2)^2(8+8\gamma-\gamma^2)^2}$
No R&D	$\frac{(a-c)^2(1+\gamma)^2\left(4+2\gamma-\gamma^2\right)^2}{(2+2\gamma-\gamma^2)^2(8+8\gamma-\gamma^2)^2}$, $\frac{(a-c)^2\left(4+3\gamma-2\gamma^2\right)^2(1+\gamma)}{2(2+2\gamma-\gamma^2)^2(8+8\gamma-\gamma^2)^2}-I$	$\frac{4(a-c)^2}{(2+\gamma)^2(4-\gamma)^2}$, $\frac{4(a-c)^2}{(2+\gamma)^2(4-\gamma)^2}$

Proposition 3 *Assume that there are decentralised labour unions.*

(a) Both firms innovate for $I < I_H^d$, and (b) neither firm innovates for $I_H^d < I$, where $I_H^d = 2(a-c)^2\left[\frac{(1+\gamma)\left(4+3\gamma-2\gamma^2\right)^2}{(2+2\gamma-\gamma^2)^2(8+8\gamma-\gamma^2)^2} - \frac{2}{(2+\gamma)^2(4-\gamma)^2}\right]$.

Proof. We get from Table 2.3 that (RD, RD) is the equilibrium strategy for $I < I_L^d$, where $I_L^d = \frac{1}{2}(a-c)^2(1+\gamma)^2\left[\frac{(1+\gamma)}{(2+\gamma)^2(1+2\gamma)^2} - \frac{\left(4+2\gamma-\gamma^2\right)^2}{(2+2\gamma-\gamma^2)^2(8+8\gamma-\gamma^2)^2}\right]$,

and (No RD, No RD) is the equilibrium strategy for $I_H^d < I$, where $I_H^d = 2(a-c)^2\left[\frac{(1+\gamma)\left(4+3\gamma-2\gamma^2\right)^2}{(2+2\gamma-\gamma^2)^2(8+8\gamma-\gamma^2)^2} - \frac{2}{(2+\gamma)^2(4-\gamma)^2}\right]$.

We also get that $I_H^d < I_L^d$. Hence, it is immediate that both firms innovate for $I < I_H^d$ and neither firm innovates for $I_L^d < I$.

If $I \in (I_H^d, I_L^d)$, we get two pure strategy equilibria: both firms innovate, and neither firm innovates. We get that each firm earns higher profit in the latter equilibrium than in the former equilibrium. Hence, following the focal point argument (Schelling, 1960), we can say that the higher profit of each firm in the latter equilibrium acts as the focal point and induces neither firm to innovate if $I \in \left(I_H^d, I_L^d\right)$.

It follows from the above argument that both firms innovate for $I < I_H^d$ and neither firm innovates for $I_H^d < I$. ■

Again, I_H^d and I_L^d show a firm's gross non-strategic and gross strategic benefits from innovation respectively.

Unlike Propositions 1 and 2, we get in Proposition 3 that the strategic benefit from innovation is higher than the non-strategic benefit from innovation, thus making "only one firm innovating" not as an equilibrium. The effects of innovation on a firm's profitability, as discussed for Proposition 1, remain even for Proposition 3. However, along with theses effects, decentralised unions create new wage effects by making the wages and therefore, the marginal costs of the firms, dependent on the number of products. Our result suggests that this wage effect reduces a firm's gain from unilateral innovation in a way so that the firm's strategic incentive for innovation is higher than its non-strategic incentive for innovation. Hence, only one firm innovating cannot be an equilibrium outcome.

2.3 The effects of the unionisation structure on innovation

Comparing the critical values mentioned in Propositions 1-3, we get the following relation:

$$I_L^c < I_H^c < I_H^d < I_L^d < I_L < I_H \tag{34}$$

for $\gamma \in [0,1]$. The above inequality suggests that, for a given cost of innovation, the number of firms investing in innovation cannot be lower under no union compared to decentralised unions. Similarly, for a given cost of innovation, the number of firms investing in innovation cannot be lower under decentralised unions compared to a centralised union.

Hence, the following proposition is immediate.

Proposition 4 *No labour union provides higher incentive for innovation compared to decentralised labour unions, which provide higher incentive for innovation compared to a centralised labour union.*

The intuition goes as follows. The union's rent seeking behaviour reduces the firms's incentive for innovation compared to no union case. Hence, it is intuitive that the firms find it more profitable to invest more under no union compared to any unionisation structure. However, since the centralised union internalises (indirect) competition across unions, which is evident under decentralised unions, the hold-up problem is higher under a centralised union than under decentralised unions, thus creating lower incentive for innovation under a centralised labour union than under decentralised labour unions.

3 The implications of asymmetric product differentiation

Considering symmetric product differentiation between the products, we have shown in Section 2 that the incentive for product innovation is higher under decentralised unions. While symmetric product differentiation is certainly an useful starting point for the analysis, there is no reason to believe that the products cannot be differentiated asymmetrically. In a more general framework, one should use separate parameters to capture the degree of product differentiation between g, h, y and z. Unfortunately, we cannot do it due to analytical tractability. However, we consider a particular type of asymmetric product differentiation in this section to show that the results of Section 2 is sensitive to the assumption of symmetric product differentiation. We show that the incentive for product innovation may be higher under a centralised union in the presence of asymmetric product differentiation.

We modify the analysis of the previous section by considering that the existing products of the firms, i.e., g and h, are perfectly substitutable. To economise the notations, let's define the existing products as product x. We keep all other assumptions of the previous section. This modification gives us the inverse market demand functions for x, y and z, respectively, as:

$$P_x = a - q_x - \gamma q_y - \gamma q_z \tag{35}$$

$$P_y = a - q_y - \gamma q_x - \gamma q_z \tag{36}$$

$$P_z = a - q_z - \gamma q_x - \gamma q_y. \tag{37}$$

We consider the game structure similar to Section 2.

3.1 The equilibrium outputs

If there is no innovation by any firm, only product x will be produced, and the inverse demand function is $P_x = a - q_x$. If the wages paid by firms 1 and 2 are w_1 and w_2 respectively, straightforward calculations show that the equilibrium outputs

of firms 1 and 2 are respectively:

$$q_{x_1}^* = \frac{1}{3}(a - 2w_1 + w_2) \tag{38}$$

$$q_{x_2}^* = \frac{1}{3}(a + w_1 - 2w_2). \tag{39}$$

Now consider the situation where only firm 1 innovates a new product and firm 2 does not innovate. This corresponds to the case of $q_z = 0$. Given the wages w_1 and w_2 for firms 1 and 2 respectively, the equilibrium outputs of firms 1 and 2 are respectively:

$$\widehat{q}_{x_1} = \left[\frac{a(2-\gamma) - (4+\gamma)w_1 + 2(1+\gamma)w_2}{6(1+\gamma)}\right] \tag{40}$$

$$\widehat{q}_{x_2} = \frac{1}{3}(a + w_1 - 2w_2) \tag{41}$$

$$\widehat{q}_y = \frac{1}{2}\left(\frac{a - w_1}{1+\gamma}\right). \tag{42}$$

If only firm 2 innovates, it implies that $q_y = 0$. In this situation, we get the equilibrium outputs as:

$$\widetilde{q}_{x_1} = \frac{1}{3}(a - 2w_1 + w_2) \tag{43}$$

$$\widetilde{q}_{x_2} = \left[\frac{a(2-\gamma) + 2(1+\gamma)w_1 - (4+\gamma)w_2}{6(1+\gamma)}\right] \tag{44}$$

$$\widetilde{q}_z = \frac{1}{2}\left(\frac{a - w_1}{1+\gamma}\right). \tag{45}$$

Finally, consider the case where both firms innovate. In this situation, given the wages w_1 and w_2 for firms 1 and 2 respectively, the equilibrium outputs are:

$$\overline{q}_{x_1} = \frac{2}{3}\left[\frac{(\gamma+2)a - (5\gamma+4)w_1 + 2(2\gamma+1)w_2}{(\gamma+2)(3\gamma+2)}\right] \tag{46}$$

$$\overline{q}_{x_2} = \frac{2}{3}\left[\frac{(\gamma+2)a + 2(2\gamma+1)w_1 - (5\gamma+4)w_2}{(\gamma+2)(3\gamma+2)}\right] \tag{47}$$

$$\overline{q}_y = \left[\frac{(\gamma+2)a - 2(\gamma+1)w_1 + \gamma w_2}{(\gamma+2)(3\gamma+2)}\right] \tag{48}$$

$$\overline{q}_z = \left[\frac{(\gamma+2)a + w_1 - 2(\gamma+1)w_2}{(\gamma+2)(3\gamma+2)}\right]. \tag{49}$$

3.2 The wage setting stage

3.2.1 No union case

First consider the case of no union or full bargaining power of the firms in wage determination. In this situation, the equilibrium wages paid by the firms are $w_1 = w_2 = c$.

Straightforward calculations show that, if neither firm innovates, the equilibrium profits are:

$$\pi_1^* = \pi_2^* = \frac{1}{9}(a-c)^2. \tag{50}$$

If only firm 1 innovates, the equilibrium profits are:

$$\widehat{\pi}_1 = \frac{1}{36}\left(\frac{13-5\gamma}{1+\gamma}\right)(a-c)^2 - I \tag{51}$$

$$\widehat{\pi}_2 = \frac{1}{9}(a-c)^2. \tag{52}$$

If only firm 2 innovates, the equilibrium profits are:

$$\widetilde{\pi}_1 = \frac{1}{9}(a-c)^2 \tag{53}$$

$$\widetilde{\pi}_2 = \frac{1}{36}\left(\frac{13-5\gamma}{1+\gamma}\right)(a-c)^2 - I. \tag{54}$$

Finally, if both firms innovate, the equilibrium profits are:

$$\overline{\pi}_1 = \overline{\pi}_2 = \frac{1}{9}\left(\frac{a-c}{2+3\gamma}\right)^2(13+12\gamma) - I. \tag{55}$$

Table 3.1 summarises the payoffs of the firms under no union conditional on the innovation strategies.

Table 3.1

Firm 2 $\rightarrow$ Firm 1 $\downarrow$	R&D	No R&D
R&D	$\frac{(a-c)^2(13+12\gamma)}{9(2+3\gamma)^2} - I$, $\frac{(a-c)^2(13+12\gamma)}{9(2+3\gamma)^2} - I$	$\frac{(a-c)^2(13-5\gamma)}{36(1+\gamma)} - I$, $\frac{(a-c)^2}{9}$
No R&D	$\frac{(a-c)^2}{9}$, $\frac{(a-c)^2(13-5\gamma)}{36(1+\gamma)} - I$	$\frac{(a-c)^2}{9}$, $\frac{(a-c)^2}{9}$

The following result is immediate from the payoff Table 3.1.

Proposition 5 *Assume that there is no labour union (or the firms have full bargaining power in wage determination).*

(a) Both firms innovate if $I < I_L$, where $I_L = \left(\frac{a-c}{2+3\gamma}\right)^2\left(1-\gamma^2\right)$.

(b) Neither firm innovates if $I_H < I$, where $I_H = \frac{1}{4}\left(\frac{1-\gamma}{1+\gamma}\right)(a-c)^2$.

(c) Only one firm innovates if $I_L < I < I_H$.

The intuition for this result is similar to that of Proposition 1.

3.2.2 A centralised union

Now consider the case of a centralised union. Like the case of symmetric product differentiation, we get in this section that the equilibrium wages are $w^c = \frac{1}{2}(a+c)$, irrespective of the innovation strategies of the firms and whether or not the union charges a uniform wage or discriminatory wages.

If neither firm innovates, we get the equilibrium profits as:

$$\pi_1^{c^*} = \pi_2^{c^*} = \frac{1}{36}(a-c)^2. \tag{56}$$

If only firm 1 innovates, the equilibrium profits of firms 1 and 2 are respectively:

$$\widehat{\pi}_1^c = \frac{1}{144}\left(\frac{13-5\gamma}{1+\gamma}\right)(a-c)^2 - I \tag{57}$$

$$\widehat{\pi}_2^c = \frac{1}{36}(a-c)^2. \tag{58}$$

If only firm 2 innovates, the equilibrium profits of firms 1 and 2 are respectively:

$$\widetilde{\pi}_1^c = \frac{1}{36}(a-c)^2 \tag{59}$$

$$\widetilde{\pi}_2^c = \frac{1}{144}\left(\frac{13-5\gamma}{1+\gamma}\right)(a-c)^2 - I. \tag{60}$$

If both firms innovate, the equilibrium profits are:

$$\overline{\pi}_1^c = \overline{\pi}_2^c = \frac{1}{36}\left(\frac{a-c}{2+3\gamma}\right)^2(12\gamma+13) - I. \tag{61}$$

The following table shows the payoffs of the firms under a centralised union, for different innovation strategies of the firms.

Table 3.2

Firm 2 $\rightarrow$ Firm 1 $\downarrow$	R&D	No R&D
R&D	$\frac{(a-c)^2(13+12\gamma)}{36(2+3\gamma)^2} - I$, $\frac{(a-c)^2(13+12\gamma)}{36(2+3\gamma)^2} - I$	$\frac{(a-c)^2(13-5\gamma)}{144(1+\gamma)} - I$, $\frac{(a-c)^2}{36}$
No R&D	$\frac{(a-c)^2}{36}$, $\frac{(a-c)^2(13-5\gamma)}{144(1+\gamma)} - I$	$\frac{(a-c)^2}{36}$, $\frac{(a-c)^2}{36}$

The following proposition is immediate from the payoff Table 3.2.

Proposition 6 *Assume that there is a centralised labour union.*

(a) Both firms innovate if $I < I_L^c$, where $I_L^c = \frac{1}{4}\left(\frac{a-c}{2+3\gamma}\right)^2\left(1-\gamma^2\right)$.

(b) Neither firm innovates if $I_H^c < I$, where $I_H^c = \frac{1}{16}\left(\frac{1-\gamma}{1+\gamma}\right)(a-c)^2$.

(c) Only one firm innovates if $I_L^c < I < I_H^c$.

The intuition is similar to the centralised union case of Section 2.

3.2.3 Decentralised unions

Now consider the case of decentralised unions. If neither firm innovates, the equilibrium wages paid and the profits of firms 1 and 2 can be found as:

$$w_1^{d^*} = w_2^{d^*} = \frac{1}{3}(a+2c) \tag{62}$$

$$\pi_1^* = \pi_2^* = \frac{4}{81}(a-c)^2. \tag{63}$$

If only firm 1 innovates, the equilibrium wages and the profits are:

$$\widehat{w}_1^d = \left[\frac{a(11-\gamma)+4c(4+\gamma)}{3(9+\gamma)}\right] \tag{64}$$

$$\widehat{w}_2^{d^*} = \left[\frac{a(\gamma+19)+5c(7+\gamma)}{6(9+\gamma)}\right] \tag{65}$$

$$\widehat{\pi}_1^d = \frac{4}{81}\left(\frac{a-c}{9+\gamma}\right)^2\left(\frac{4+\gamma}{1+\gamma}\right)(7+\gamma)(7-2\gamma) - I \tag{66}$$

$$\widehat{\pi}_2^d = \frac{5}{162}\left(\frac{a-c}{9+\gamma}\right)^2(7+\gamma)(19+\gamma). \tag{67}$$

If only firm 2 innovates, the equilibrium wages and profits are:

$$\widetilde{w}_1^d = \left[\frac{a(\gamma+19)+5c(7+\gamma)}{6(9+\gamma)}\right] \tag{68}$$

$$\widetilde{w}_2^d = \left[\frac{a(11-\gamma)+4c(4+\gamma)}{3(9+\gamma)}\right] \tag{69}$$

$$\widetilde{\pi}_1^d = \frac{5}{162}\left(\frac{a-c}{9+\gamma}\right)^2(7+\gamma)(19+\gamma) \tag{70}$$

$$\widetilde{\pi}_2^d = \frac{4}{81}\left(\frac{a-c}{9+\gamma}\right)^2\left(\frac{4+\gamma}{1+\gamma}\right)(7+\gamma)(7-2\gamma) - I. \tag{71}$$

Finally, consider the case where both firms innovate. In this situation, the equilibrium wages and profits are:

$$\overline{w}_1^d = \overline{w}_2^d = \left[\frac{5a(2+\gamma)+2c(7+8\gamma)}{3(8+7\gamma)}\right] \tag{72}$$

$$\overline{\pi}_1^d = \overline{\pi}_2^d = \frac{4}{81}\left[\frac{(7+8\gamma)(a-c)}{(2+3\gamma)(8+7\gamma)}\right]^2(13+12\gamma) - I. \tag{73}$$

The following table shows the payoffs of the firms under decentralised unions, for different innovation strategies of the firms.

Table 3.3

Firm 2 $\rightarrow$ Firm 1 $\downarrow$	R&D	No R&D
R&D	$\frac{4(a-c)^2(7+8\gamma)^2(13+12\gamma)}{81(2+3\gamma)^2(8+7\gamma)^2} - I,$ $\frac{4(a-c)^2(7+8\gamma)^2(13+12\gamma)}{81(2+3\gamma)^2(8+7\gamma)^2} - I$	$\frac{4(a-c)^2(4+\gamma)(7+\gamma)(7-2\gamma)}{81(9+\gamma)^2(1+\gamma)} - I,$ $\frac{5(a-c)^2(7+\gamma)(19+\gamma)}{162(9+\gamma)^2}$
No R&D	$\frac{5(a-c)^2(7+\gamma)(19+\gamma)}{162(9+\gamma)^2},$ $\frac{4(a-c)^2(4+\gamma)(7+\gamma)(7-2\gamma)}{81(9+\gamma)^2(1+\gamma)} - I$	$\frac{4(a-c)^2}{81},$ $\frac{4(a-c)^2}{81}$

Proposition 7 *Assume that there are decentralised labour unions.*

(a) If $\gamma < 0.68$*, (i) both firms innovate for* $I < I_L^d$*, (ii) neither firm innovates for* $I_H^d < I$*, and (iii) only one firm innovates for* $I_L^d < I < I_H^d$*, where* $I_L^d = \left[\frac{4}{81}\left(\frac{(7+8\gamma)(a-c)}{(2+3\gamma)(8+7\gamma)}\right)^2(13+12\gamma) - \frac{5}{162}\left(\frac{a-c}{9+\gamma}\right)^2(7+\gamma)(19+\gamma)\right]$ *and*

$I_H^d = \frac{4}{81}(a-c)^2\left[\left(\frac{1}{9+\gamma}\right)^2\left(\frac{4+\gamma}{1+\gamma}\right)(7+\gamma)(7-2\gamma) - 1\right]$.

(b) If $\gamma > 0.68$*, (i) both firms innovate for* $I < I_L^d$*, and (b) neither firm innovates for* $I_L^d < I$*.*

Proof. We get from Table 3.3 that (RD, RD) is the equilibrium strategy for $I < I_L^d$ and (No RD, No RD) is the equilibrium strategy for $I > I_H^d$. we also get that $I_L^d < I_H^d$ for $\gamma < 0.68$. Hence, the first part of the proposition is immediate.

If $\gamma > 0.68$, we get that $I_H^d < I_L^d$, and the second part of the proposition follows from the focal point argument similar to Proposition 3. ■

The intuition for the above result is similar to Proposition 3 with the exception that, in the presence of asymmetric product differentiation, the wage effects are not strong enough to create a firm's strategic incentive for innovation higher than its non-strategic incentive for innovation for large product differentiation (i.e., for $\gamma < 0.68$).

3.3 The effects of the unionisation structure on innovation

We are now in position to show the effects of the unionisation structure on innovation.

The comparison of the critical values shown in Propositions 5-7 gives Lemmas 1 and 2 immediately.

Lemma 1 *If* $\gamma \in [0, 0.54)$*, we get that:*

(a) $I_L^c < I_H^c < I_L^d < I_H^d < I_L < I_H$ *for* $0 < \gamma < 0.13$.

(b) $I_L^c < I_L^d < I_H^c < I_H^d < I_L < I_H$ *for* $0.13 \leqslant \gamma < 0.54$.

Lemma 1 considers the situation where the products are sufficiently differentiated and shows that the presence of labour union reduces the gross benefits from innovation compared to the situation with no labour union, irrespective of the unionisation structure, thus implying that the incentive for innovation is higher under no labour union than under labour union. However, while looking at the innovation incentives under different labour unionised structure, Lemma 1 shows that the decentralised

unions provide higher incentive for innovation compared to a centralised union if the products are sufficiently differentiated. Lemma 1 suggests that, if the products are very much differentiated, the stronger hold-up problem under a centralised union compared to the decentralised unions reduces the firms' incentive for innovation under the former unionisation structure compared to the latter unionisation structure.

Lemma 2 *If* $\gamma \in (0.54, 1)$*, we get that:*
(a) $I_L^c < I_L^d < I_H^d < I_H^c < I_L < I_H$ *for* $0.54 \leqslant \gamma < 0.68$*.*
(b) $I_L^c < I_H^d < I_L^d < I_H^c < I_L < I_H$ *for* $0.68 \leqslant \gamma < 0.74$*.*
(c) $I_H^d < I_L^c < I_L^d < I_H^c < I_L < I_H$ *for* $0.74 \leqslant \gamma < 1$*.*

Like Lemma 1, Lemma 2 also shows that the incentive for innovation is higher under no labour union than under labour union, irrespective of the unionisation structure. However, while looking the effects of different labour unionisation structure, Lemma 2 shows that a centralised union may provide higher incentive for innovation compared to decentralised unions.

Combining the results of Lemma 1 and Lemma 2, we get the following result immediately.

Proposition 8 *(a) The presence of labour union reduces the incentive for innovation compared to no labour union, irrespective of the labour unionisation structure.*

(b) The incentive for innovation is higher under decentralised labour unions compared to a centralised labour union if the existing products are sufficiently differentiated from the new products (i.e., for $0 < \gamma < 0.54$*).*

(c) The incentive for innovation may be higher under a centralised labour union than under decentralised labour unions if the existing products are not very differentiated from the new products (i.e., $0.54 \leqslant \gamma < 1$*).*

The above result suggests that whether the hold-up problems under a centralised union is higher or lower than that of under decentralised unions depends on the degree of product differentiation. If the products are very much differentiated such that the existing and the new products are almost isolated, the new products do not have significant effects on the market shares and therefore, on the labour demands for the existing products. In this situation, the hold-up problem is higher under a centralised union than under decentralised unions, and the incentives for innovation are higher under the latter unionisation structure than the former.

Now consider the effects of product differentiation on the profits under innovation and no innovation. If the product differentiation reduces, it increases competition between the existing and the new products and reduces the total profits of the firms under innovation and no innovation while looking at the strategic incentive for innovation. However, lower product differentiation reduces the total profits of the firms only under innovation while looking at the non-strategic incentive for innovation, since the profits under no innovation do not depend on the degree of product differentiation in this situation. These profit losses occur under both unionisation structure. However, since the outputs of the firms are higher under decentralised

unions than under a centralised union, the loss of profits due to the lower product differentiation is higher under decentralised unions than under a centralised union. We find that if the products are close substitutes, the loss of profit under unilateral innovation is sufficiently higher for the decentralised unions than under a centralised union, thus creating higher non-strategic incentive for innovation under a centralised union than under decentralised unions. However, since the profits under both innovation and no innovation reduce with lower product differentiation for the strategic incentive for innovation, the net profit loss under decentralised unions do not dominate that of under a centralised union in this situation, and the strategic incentive for innovation is higher under decentralised unions than under a centralised union, irrespective of the degree of product substitutability.

4 Conclusion

We show the effects of the labour union and the labour unionisation structure on the incentive for product innovation. The presence of labour union reduces the incentive for innovation compared to the situation with no labour union (or if the unions have no bargaining power in wage determination). However, the effects of the labour unionisation structure on innovation are not so straightforward. We show that if the products are symmetrically differentiated, the incentive for innovation is higher under decentralised labour unions than under a centralised labour union. However, if the products are asymmetrically differentiated, the incentive for innovation may be higher under a centralised labour union than under decentralised labour unions depending on the degree of product differentiation. While few recent papers have tried to uncover the effects of different unionisation structure on process innovation, our paper provides a new perspective to the literature by focusing on product innovation.

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