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Union structure and firms' incentives for cooperative R&D investments

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Abstract

We examine how different unionisation structures and the spillovers of R&D activities affect R&D investments and firms' incentives to form a Research Joint Venture. We find that whenever firms invest non-cooperatively, an industry union increases R&D investments, if industry specific spillovers are low. In case of a Research Joint Venture, investments are always higher under firm-level unions. We also find that firms' incentives to form a Research Joint Venture are stronger when they face an industry union, if spillovers are low. Rigidities in the labour market, such as high unemployment benefits or/and a central union, have negative effects on employment, output and profits and hinder the diffusion of the efficiency created by a RJV to consumers and employees. Integrated labour market and R&D policies are also discussed.

JEL classification: J51; L13; O31

Keywords: Trade Unions; Oligopoly; Process Innovations

1 Introduction[1]

It is well established that innovations in the production process affect firms' profits, employment and wages. Due to the effects of process innovations on employees, labour market institutions, and especially labour unions, are amongst the key determinants of firms' strategies for process innovations' R&D investments. In this field, theoretical and empirical work is mixed (for a survey, see

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Menezes-Filho and Van Reenen, 2003). Hirsch (2004) underlines that the existing empirical evidence does not allow us to establish (or reject) causal union effects and their magnitudes. Thus, the argument for the "two faces of unionism", first mentioned by Freeman and Medoff (1984), remains robust, even now, twenty years later.[2]

The formal debate for the effects of unions on firms' investments for productivity enhancing innovations has its origins on the seminal paper of Grout (1984).[3] The conventional "rent-extracting" argument indicates that as far as unions raise wages and other labour costs, the stronger the bargaining power of unions, the higher the rents that they capture. Thus, unions will reduce firms' profits and returns on R&D investments. Firms know this *ex ante* and as a result they invest low amounts (underinvest) in R&D for process innovations.[4]

In the recent literature, the rent-extracting potential of unions has been formalized in "institutional" terms, rather than in terms of bargaining power distribution between firms and unions. The institutional approach indicates that the more *centralised* the collective bargaining system, the weaker the competition and the stronger the coordination between unions. Thus, a centralised system of collective bargaining enables unions to demand higher wages and strengthens their rent-extracting potential. It should be mentioned that this approach incorporates the differences in the level where wages are set across industries and countries.[5] Calabuig and Gonzalez-Maestre (2002) show that for a small market size, a labour-saving process innovation is more likely to be adopted by a firm in the presence of a centralised union -compared with a decentralised one- a result which contradicts also with the conventional argument. In the same lines, Haucap and Wey (2004), in a framework where two firms engage in a patent race

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[2] While the monopoly 'face' of unions focuses on their wage demands and thus on their negative effects, the second 'face' focuses on the role of unions as an efficiency-enhancing institution due to its role in smoothening industrial relations.

[3] In a "one firm-one union" framework, Grout (1984) shows that in the absence of legally binding contracts, once the firm has invested in a particular level of capital, the union will have incentives to demand a higher wage in order to extract a share of rents and this drives to underinvestment.

[4] Early theoretical work on the relationship between unionisation and innovative activity had focused on the effects of firm-level unions' bargaining power has on firms' incentives to invest for labour savings innovations. Tauman and Weiss (1987), incorporating strategic interaction between firms that undertake R&D projects in a tournament R&D setup, show that the unionised duopolist, compared with the nonunionised one, has a greater incentive to adopt the new technology which drives to lower labour requirements. Ulph and Ulph (1994, 1998) consider a Cournot duopoly, where two firms, that are in a race for a labour saving process innovation, bargain with two firm-level unions over employment and wages ("Efficient Bargaining"). They prove that a stronger risk-averse union (a union that weights employment more than wages in the utility function) encourages its firm to increase investment in order to win the patent race. The result will be a higher market share which will make both the union and the firm better off.

[5] Evidence by Flanagan (1999) indicates that in the U.S.A., Canada, Japan and U.K., bargaining over wages takes place at the level of firm. In Europe, wage negotiations are often conducted at various levels: In Italy, the Netherlands, Spain, France and Portugal, bargaining takes place at the sector-level. In Germany and the Scandinavian countries, bargaining takes place at both the national and the sector-level and at all three levels (national-, sector-, and firm-level) in Belgium and Greece.

for a labour-saving process innovation, show that innovation incentives are not monotone in the degree of centralisation of wage-bargaining: Innovation incentives are the largest when an industry union sets a uniform wage, but incentives under a central union that coordinates, through wage discrimination, the wage demands of two firm-level unions are weaker than incentives under perfectly decentralised firm-level bargaining.[6]

However, in the bulk of the literature, two well established determinants of amounts invested in R&D have not been taken into account: The first is the spillover effect of R&D activities and the second is the organizational form of R&D investments and whether firms invest strategically or cooperatively, by forming a Research Joint Venture (RJV hereafter).[7] In their seminal paper, d' Aspremont and Jacquemin (1988) define that 'R&D externalities or spillovers imply that some benefits of each firm's R&D flow without compensation to other firms and this may cause free-riding behaviour and underinvestment problems'. Thus, firms may form a RJV in order to internalize spillovers and to avoid free-riding. Hagedoorn et al. (2000) and Caloghirou et al. (2003), surveying a great series of theoretical and empirical papers, conclude on some consistent findings according to the advantages of RJVs: Internalizing R&D spillovers, cost sharing, reducing R&D duplication, access to complementary resources and skills, exploiting economies of scale and scope, distributing the investment risk to more investors and promoting technical standards are strong incentives for R&D cooperation.[8]

The purpose of this paper is precisely to incorporate the spillover effects and the RJV potential in the literature for the union effects on process innovations R&D investments. In this framework, we address the following questions: Firstly, "how does the interaction between R&D spillovers and the rent-extracting of unions affect firms' amounts invested in cases of non-cooperative

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[6]Menezes-Filho and Van Reenen (2003), surveying the bulk of the empirical literature in the field, conclude on consistently strong and negative impacts of unions on R&D expenditures for the case of North America unlike for the case of Europe, where no safe pattern can be reached. According to the effects of unions on innovations, U.S. studies find significant negative effects, while European studies find insignificant, but in summary, the findings are even less clear due to very limited number of papers. Thus, the authors conclude that no safe pattern, according to the causal effects of unions, can be reached.

[7]Although R&D spillovers have not been taken into account in any of the above formal models, empirical findings suggest that spillovers affect competitors' average cost (Bernstein and Nadiri, 1989), labour productivity and total factor productivity (Coe and Helpman, 1995; Frantzen, 2000). Benfratello and Sembenelli (2002) find a positive correlation between participation, labour productivity and price-cost margin for European firms participating in RJVs, sponsored under the EUREKA project during 1992-1996.

[8]Hagedoorn and van Kranenburg (2003) establish the growing trends of RJVs as an R&D organizational form. Caloghirou et al. (2003), exploring the existing databases (MERIT-CATI, NCRA-RJV, CORE, STEP TO RJV), demonstrate that the number of new partnerships set up annually increased from about 30–40 in the early seventies to 100–200 in the late seventies. Starting from around 200 per year, the number of new partnerships announced every year reached around 600 or more in the eighties and nineties. Especially for the case of the E.U., Benfratello and Sembenelli (2002) mention that 1031 RJVs were sponsored under the EUREKA project over the 1985–1996 period and 3874 RJVs were financed under the 3rd and 4th Framework Programs for Science and Technology (FPST) over the 1992–1996 period.

and cooperative R&D investments?" and secondly, "how does the level of wage-setting affect firms' incentives to move from a strategic structure of R&D investments towards a RJV?"

In order to answer these questions, we consider a homogeneous good Cournot duopoly where symmetric firms invest in R&D for cost reducing process innovations. Firms can invest either non-cooperatively, or by forming a RJV, while R&D activities exhibit spillovers. In the spirit of d'Aspremont and Jacquemin (1988) and Kamien et al. (1992), spillovers are considered to be industry specific and exogenous. In the labour market, workers are organized either in firm-level unions or in a central union and the bargaining between firms and union(s) is carried out over wage.[9]

Our results indicate that the effect of the union structure, and the corresponding rent-extracting potential, on R&D investments, depends on whether spillovers lead to free-riding or being internalized. In case of non-cooperative investments, where spillovers lead to free-riding, a central union may lead to investment increases, if free-riding is weak. We argue that when competition is fierce, in terms that firms behave strategically in both R&D and output stages, it is the combination of weak free-riding, that favours, and single union's strong pressure, that forces, firms to increase R&D investments. This result contradicts with the hold-up argument which predicts that the stronger rent-extracting by a central union leads to underinvestment per se. In case of a RJV, where spillovers are internalized, investments are higher under firm-level unions. In this case, competition is less fierce. Firms invest cooperatively in the R&D stage, they internalize spillovers and avoid free-riding. Subsequently, it is the level where wages are set that mainly drives investments. Although a central union may favour R&D investments in case of non-cooperation, we find that it always reduces employment, output and profits under non-cooperative and cooperative R&D investments as well. Additionally, rigidities in the labour market, such as high unemployment benefits, increase wages and hinder R&D investments, employment and output.

According to firms' incentives to form a RJV, we prove that these are stronger when they face an industry union, if internalized spillovers through the RJV are low. Whenever internalized spillovers are low, a central union never captures a higher wage under the RJV, compared with wage in case of non-cooperating investments, while firm-level unions may capture higher wages.

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[9]In the literature for productivity enhancing process innovations, innovations are considered to be either 'input-saving' or 'cost-reducing'. The literature on the relationship between unionisation and innovative activity has focused on the 'labour-saving' process innovations solely. Firms undertake R&D investments in order to reduce their labour requirement, and the corresponding labour cost, per unit of output. In this case, the unit cost reduces and the productivity enhances through the reduction of labour requirement per unit of output. We rather examine the case of 'cost-reducing' process innovations, assuming that firms engage in R&D investments in order to reduce their unit cost of transformating labour to the final good. In this case, it is the reduction of the transformation cost per unit of output that reduces the unit cost and enhances the productivity. However, the above types of process innovations can be considered as equivalent, in terms that both lead to unit cost reduction and productivity enhancement, although the paths followed differ.

Therefore, the efficiency of the RJV, as a weapon to overcome rent-extracting is higher if internalized spillovers are low. As far as a central union may favour the formation of a RJV more than firm-level unions do, our argument goes against the conventional argument for the negative effects of unions per se. We further conclude that although a RJV, compared with non-cooperation, performs better in terms of R&D investments, wages, employment and output, if internalized spillovers exceed a critical rate, the intense 'rationally myopic' behaviour (Hirsch, 2004) of a central union and its higher wage demands deter employment and output increases and subsequently hinder investments, employment and output increases and subsequently hinder the diffusion of the efficiency created by a RJV to consumers and employees.

We also apply our model for the case of Bertrand competition and for the case where the rent-extracting potential of unions is modelled by the combination of the institutional level where wages are set and the distribution of bargaining power between firms and unions. Our results remain robust and therefore we contribute to the relevant literature as we prove that it is the institutional level of wage-bargaining, rather than the distribution of bargaining power, that mainly drives the results.

Our welfare analysis reveals a consistent depression in consumers surplus and social welfare in case of a centralised system of wage-setting, for both organizational forms of R&D activities. In addition, although a RJV is always profitable for firms, it does not always lead to enhanced social welfare. The economic rationale behind this result lays in deterring effects of a central union on the diffusion of the efficiency created by a RJV to consumers and employees. We also mention the difficulties for the alignment between firms' and regulators' preferences, caused by a centralised system of bargaining, a novel argument in the literature as well. Our policy implications suggest an integrated labour market and R&D policies framework. Extending antitrust rules to labour markets, reducing unemployment benefits and encouraging RJVs, can be an integrated framework to improve market performance and consumers surplus as well.

The rest of the paper is organized as follows: In section 2, we present the model. In section 3, we analyze the case of non-cooperative R&D investments, for firm-level unions and an industry-wide union. In section 4, we examine the case of a RJV for both levels of unionisation as well. In section 5, we analyze firms' incentives to form a RJV, and in section 6, we discuss some extensions of our model. In section 7 we carry out the welfare analysis and suggest policy implications. Finally, section 8 offers the conclusion of this paper.

2 The model

2.1 The product market

We consider a homogeneous goods Cournot duopoly with firms $i, j = 1, 2, i \neq j$ and a linear inverse demand function, given by $P(Q) = a - Q$, where $q_1 + q_2 = Q$ is aggregate output. Firms operate under constant returns to scale and we

normalize output to employment, using a production function of the form $q_i = L_i$. Firm i requires L_i units of labour for q_i units of the final good. Employees are identically skilled and we let the wage for employees in firm i to be w_i. We also assume that the marginal cost of transformating labour into the final good is c. Firm i can invest in R&D for cost-reducing process innovations. The overall marginal cost is given by $w_i + c - x_i - \delta x_j$. x_i is the cost reduction due to firm i's R&D investment, while x_j is the benefits that leak from firm j to firm i without compensation, due to the spillovers of R&D activities. δ is the spillover rate, indicating the R&D externalities, with $0 \le \delta \le 1$. The cost of R&D is x_i^2, reflecting the existence of diminishing returns to R&D expenditures. Thus, firm i has a total cost function, $C_i = (w_i + c - x_i - \delta x_j) L_i - x_i^2, i, j = 1, 2, i \ne j$.

We consider that in this industry, R&D can be carried out under two alternative organizational forms:

I. Non-cooperatively, where duopolists carry out their R&D activities strategically. Formally speaking, firms act non-cooperatively in both R&D and output stages.

II. Cooperatively, where the firms form a RJV and enjoy the common R&D output. In this case, firms cooperate in order to maximize their joint profits in the R&D stage, although remaining competitors in the output stage.[10]

2.2 The labour market

We consider that employees are organized either in two firm-level unions (Decentralised regime, denoted by D), which are identical and endowed with the same bargaining power during negotiations with firms, or in one industry union (Centralised regime, denoted by C). The structure of the labour market is assumed to be exogenously given. We further consider that unions act as *rent-maximizers*. Unions care about the 'real wage surplus' of their members, the difference between w_i, the real wage bill in the unionised sector, and w_0, the workers' *outside option*.[11] In case of two firm-level unions, the utility function for the union in firm i is $U_i(w_i, L_i) = (w_i - w_0) L_i$, while, in case where a central union demands a uniform wage $w_i = w_j = w$, its utility function becomes $U(w, L_i, L_j) = (w - w_0)(L_i + L_j)$.[12] Moreover, we adopt the following ver-

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[10] In some cases in the RJV literature it is assumed that, prior to the formation of a RJV spillovers are $\delta < 1$, while the RJV leads to $\delta = 1$. Following d' Aspremont and Jacquemin (1988), we rather consider that pre-RJV spillovers and post-RJV spillovers are equal and industry specific.

[11] In the trade unions literature, w_0 is typically treated to be a weighted average of the competitive wage and the unemployment benefit, the weights being the probabilities to find or not a job in the competitive sector. In our model, however, w_0 can be captured by the amount of the unemployment benefit, set by a regulator. Therefore, w_0 can be a labour market policy instrument.

[12] We believe that these unionisation structures incorporate not only the wide variations in the organization of trade unions across different countries and industries, mentioned by Flanagan (1999) but also the varieties in the level of bargaining across countries with the most RJV active firms. The decentralized system of wage-setting fits very well with the case of the U.S.A., U.K. and Japan, world wide leaders in cooperative R&D partnerships (see Caloghirou et al., 2003), while the centralized system fits well with collective bargaining

sion of the Right-to-Manage bargaining model: The union(s) set(s) the wage(s), while firms retain the right to set employment L_i and quantities q_i of the final good.[13] [14]

2.3 The sequence of decisions

To study how the interaction between the institutional level of wage-setting and R&D spillovers affect firms' investments in R&D for cost-reducing process innovations and incentives to form a RJV, we consider a four stage game with the following timing:

Stage 1: Firms decide simultaneously, whether to cooperate (c) by forming a RJV or to invest non-cooperatively (nc) in R&D.

Stage 2: Firms invest in R&D.

Stage 3: Unions set wages, either at the level of firm (D) or at the level of industry (C).

Stage 4: Firms set quantities.

We firstly consider that firms invest non-cooperatively, for every level of wage-setting, e.g. through a strict antitrust law enforcement that forbids RJVs. Then, we consider that firms invest cooperatively, by forming a RJV. Finally, we endogenize firms' decision to cooperate or not and therefore, we examine whether firms have incentives to form a RJV, for every structure of the labour market. We solve the game using Backwards Induction, in order to define the Subgame Nash Perfect Equilibrium (SPNE).

3 Non-cooperative R&D investments[15]

3.1 The case of firm-level unions

We begin our analysis by considering the case where firms invest non-cooperatively (denoted by nc) in R&D for cost-reducing innovations. Regardless the level

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systems in countries (e.g. Italy, Germany, France and Belgium) with the higher participation in RJVs across the European Union (see Benfratello and Sembenelli, 2002).

[13] Following Haucap and Wey (2004), we regard that unions unilaterally set wages. Although in real life the wage rate and (possibly) the employment level is determined via firm-union negotiations, it is a regular assumption in the "union-oligopoly bargaining" literature that the union has all the power in wage negotiations, while the firm has all the power to set the employment level (see Petrakis and Vlassis, 2004 and the references therein). In section 6.1 we consider the general version of the Right to Manage model, where firms do have bargaining power over employment, and we confirm the robustness of the qualitative results obtained under monopoly-unions.

[14] Even if union(s) have a utalitarian-type objective (Oswald, 1982), $U_i(w_i, L_i) = (w_i - w_0)^\varphi L_i$ with $\varphi \in (0, 1]$ being the elasticity of substitution between wage level and employment of the union, qualitatively similar results can be obtained.

[15] As a benchmark for later comparison, we consider the case of a perfectly competitive labour market, where employees earn the wage paid in the competitive sector of the economy, $w_i = w_j = w_0$. Similarly, in this case we regard the absence of labour unions, case (N). In this benchmark case, we find that a RJV increases investments if $\delta > 0.5$, while it is always profitable for firms. A detailed analysis is available from the authors on request.

where wages are set, in the last stage of the game, given R&D investments and wages, each firm i sets production level in order to maximize profits given by:

$$\Pi_i\left(L_i, L_j, w_i, x_i, x_j, \delta\right) = \left(a - L_i - L_j - w_i - c + x_i + \delta x_j\right) L_i - x_i^2 \quad (1)$$

Solving first order conditions, we compute the Nash-Cournot employment and quantity levels:[16]

$$q_i^* = L_i^* = \frac{1}{3}\left[(a-c) - 2w_i + w_j + x_i\left(2 - \delta\right) + x_j\left(2\delta - 1\right)\right] \quad (2)$$

An increase in w_i reduces q_i^* and moreover, an increase in w_j increases q_i^* through the reduction of q_j^*. Firm i's output and employment increase not only with i's R&D investment but with j's as well, indicating the positive spillover effect of R&D activities and implying the benefits of j's R&D efforts on i's output, but firm i's R&D investment has always larger impact on its own output than j's R&D impact has, as $2 - \delta \geq 2\delta - 1$, for $0 \leq \delta \leq 1$, always holds. In the case of perfect spillovers ($\delta = 1$, e.g. firms share the same R&D laboratory), i's and j's R&D investments have equal impact on each firm's output.

Given q_i^* and q_j^* and assuming that wages are set at the level of firm (D structure), in the third stage, firm-level unions set wages simultaneously and non-cooperatively so as to maximize their rents:[17]

$$\underset{w_i}{Max} U_i = \frac{1}{3}\left(w_i - w_0\right)\left[(a-c) - 2w_i + w_j + x_i\left(2 - \delta\right) + x_j\left(2\delta - 1\right)\right] \quad (3)$$

Union i's utility increases with firm i's and firm j's R&D investment. From the first order conditions of eq. (3), we find the wage for employees in firm i:

$$w_i = \frac{1}{15}\left[5\left(a - c + 2w_0\right) + x_i\left(7 - 2\delta\right) + x_j\left(7\delta - 2\right)\right] \quad (4)$$

$7 - 2\delta \geq 7\delta - 2$ always holds and therefore, firm i's R&D investment has always larger impact -than j's- on union i's wage.

In the second stage of the game, firms set simultaneously their R&D investment levels (x_1, x_2) so as each firm to maximize its profits:

$$\underset{x_i}{Max}\Pi_i = \frac{4\left[5\left(a - c - w_0\right) + x_i\left(7 - 2\delta\right) + x_j\left(7\delta - 2\right)\right]^2}{2025} - x_i^2 \quad (5)$$

Solving eq. (5), the unique and symmetric solution for the optimal non-cooperative R&D investment levels in equilibrium is:

$$x_i^* = \frac{\left(28 - 8\delta\right)\left(a - c - w_0\right)}{377 - 20\delta + 8\delta^2} \quad (6)$$

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[16] We consider that $c \leq a$.

[17] In order to ensure that employees' in firm i wage has a positive effect on their utility, we regard that $(a - c) - 2w_i > 0 \Rightarrow 2w_i < \frac{1}{2}\left(a - c\right)$

Using (2), (4), (5) and (6) we find that if firms do not cooperate (nc) in R&D and wages are set by two firm-level unions (D structure), total R&D investment $\left(X^D_{nc} = x^*_1 + x^*_2\right)$, firm-level wages $\left(w^D_{inc}\right)$, total employment and quantity $\left(L^D_{nc} = L^*_1 + L^*_2\right)$ and firm i's profits $\left(\Pi^D_{inc}\right)$ are:

$$X^D_{nc} = \frac{(56 - 16\delta)(a - c - w_0)}{377 - 20\delta + 8\delta^2} \tag{7}$$

$$w^D_{inc} = \frac{135(a - c) + w_0\left(242 - 20\delta + 8\delta^2\right)}{377 - 20\delta + 8\delta^2} \tag{8}$$

$$L^D_{nc} = \frac{180(a - c - w_0)}{377 - 20\delta + 8\delta^2} \tag{9}$$

$$\Pi^D_{inc} = \frac{\left(7316 + 448\delta - 64\delta^2\right)(a - c - w_0)^2}{\left(377 - 20\delta + 8\delta^2\right)^2} \tag{10}$$

3.2   The case of one industry union

Let us now examine the case where a uniform wage is determined at the level of industry (C structure). In the last stage of the game, output and employment are given by:

$$q^*_i = L^*_i = \frac{1}{3}\left[(a - c) - w + x_i(2 - \delta) + x_j(2\delta - 1)\right] \tag{11}$$

In the wage-determination stage, the central union maximizes:[18]

$$\underset{w}{Max}U = \frac{1}{3}(w - w_0)\left[2(a - c) - 2w + (x_i + x_j)(1 + \delta)\right] \tag{12}$$

Maximization of eq. (12) gives the uniform wage for employees:

$$w = \frac{1}{4}\left[2(a - c - w_0) + (x_i + x_j)(1 + \delta)\right] \tag{13}$$

The wage depends positively not only on firm i's amount invested in R&D but also on firm j's, due to the spillover effects of R&D activities.

In the second stage of the game firms set simultaneously their R&D investments (x_i, x_j) so as each firm to maximize its profits:

$$\underset{x_i}{Max}\Pi_i = \frac{\left[2(a - c - w_0) + x_i(7 - 5\delta) + x_j(7\delta - 5)\right]^2}{144} - x^2_i \tag{14}$$

and the optimal non-cooperative R&D investment for firm i is:

$$x^*_i = \frac{(7 - 5\delta)(a - c - w_0)}{65 - 2\delta + 5\delta^2} \tag{15}$$

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[18] In order to ensure that uniform wage has a positive effect on employees utility, we regard that $2(a - c) - 2w > 0 \Rightarrow w < a - c$

Using (11), (13), (14) and (15) we find that when firms do not cooperate (nc) in R&D and a central union sets the wage (C structure), total R&D investment $\left(X_{nc}^{C}\right)$, industry-level wage $\left(w_{nc}^{C}\right)$, total employment and quantity $\left(L_{nc}^{C}\right)$ and firm i's profits $\left(\Pi_{inc}^{C}\right)$ are:

$$X_{nc}^{C} = \frac{(14 - 10\delta)(a - c - w_0)}{65 - 2\delta + 5\delta^2} \tag{16}$$

$$w_{nc}^{C} = \frac{36(a - c) + w_0\left(29 - 2\delta + 5\delta^2\right)}{65 - 2\delta + 5\delta^2} \tag{17}$$

$$L_{nc}^{C} = \frac{24(a - c - w_0)}{65 - 2\delta + 5\delta^2} \tag{18}$$

$$\Pi_{inc}^{C} = \frac{\left(95 + 70\delta - 25\delta^2\right)(a - c)^2}{\left(65 - 2\delta + 5\delta^2\right)^2} \tag{19}$$

For the case of non-cooperative R&D investments, comparing results under a decentralised system of wage-setting (D), with results under a central union (C), we state the following proposition:

Proposition 1 *(i) Total R&D investments in the industry are higher under a centralised system of wage-setting, compared with the decentralised one, if spillovers are low ($\delta < 0.55$). (ii) Firms' profits and employment (wages) are always higher (lower) under a decentralised system of wage-setting, compared with a centralised one.*

According to the total R&D investments, the intuition behind our result goes as follows: When firms invest in R&D non-cooperatively, investments depend on the following determinants: Free-riding and unions' rent-extracting. In case of no free-riding ($\delta = 0$), investments under a central union are always higher than investments under firm-level unions, in contrast to the hold-up argument. Although an industry union always extracts higher rents $\left(w^C > w_i^D\right)$, its comparative stronger pressure increases R&D investments, rather than to decrease them. As free-riding arises, ($\delta > 0$), only if it is weak ($\delta < 0.55$) the single union's pressure dominates the negative effect of free-riding and $X^C > X^D$ holds. We argue that when competition is fierce, in terms that firms behave strategically in both R&D and output stages, the central union's pressure, increases R&D investments, if free-riding is weak. It is the combination of low spillovers, that favour, and central union's strong pressure, that forces, firms to increase R&D investments. This result contradicts with the conventional argument which indicates that the stronger the rent-extracting of unions, the lower the amounts that firms invest per se.

According to wages, employment, output and profits the intuition goes as follows: Firms invest in R&D and as a result the overall marginal cost falls. The price of the final good decreases, demand for the final good increases and demand for labour increases too. As the demand for labour increases, unions

extract rents through demanding higher wages. A central union extracts more rents, than two firm-level unions do $\left(w_{nc}^C > w_{inc}^D\right)$. The lower the intraunion competition, the stronger the hold-up, the higher the wages that employees earn and the lower the employment $\left(L_{inc}^C < L_{inc}^D\right)$ and firms' profits. This is the rational why wages are always higher under a centralised system of wage-setting, while firms' profits are always lower $\left(\Pi_{inc}^C < \Pi_{inc}^D\right)$. Note that, although a central union may favour R&D investments, it always reduces employment, output and profits. Additionally, qualitative analysis of the results shows that rigidities in the labour market, such as high unemployment benefits, increase wages and hinder R&D investments, employment and output, as far as $\frac{dW_{nc}}{dw_0} > 0$, $\frac{dX_{nc}}{dw_0} < 0$ and $\frac{dL_{nc}}{dw_0} < 0$ always hold, regardless the level where wages are set. Our results are in line with the empirical findings, according to which, process innovations lead generally to wage and employment increases (Chennells and Van Reenen, 2002).

In figures 1a and 1b, we plot our results for firm-level profits and total R&D investment in the industry.[19] We observe that regarding as a benchmark the case of a perfectly competitive labour market and taking into account unions' rent-extracting in an imperfectly competitive labour market, firm i's profits and total R&D investments decrease, which is in line with the "hold-up" argument. But, according to investments, we proved that this argument does not holds per se, because if $\delta < 0.55$, investments are higher under a centralised system of wage-setting, compared with a decentralised one.
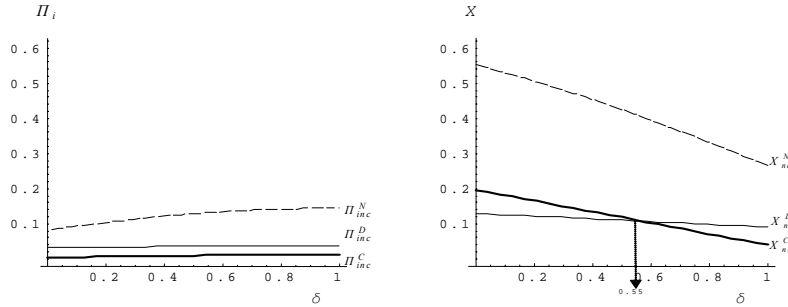

Figure 1: Non-cooperative R&D investments. 1a: Firm-level profits in case of no unions $\left(\Pi_{inc}^N\right)$, two firm level unions $\left(\Pi_{inc}^D\right)$ and a central union $\left(\Pi_{inc}^C\right)$. 1b: Industry-wide R&D investments, in case of no unions $\left(X_{nc}^N\right)$, two firm level unions $\left(X_{nc}^D\right)$ and a central union $\left(X_{nc}^C\right)$.

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[19]We divide equations that correspond to industry-wide R&D investments with $(a - c - w_0)$ and equations that correspond to firm-level profits with $(a - c - w_0)^2$.

4 Cooperative R&D investments

4.1 The case of firm-level unions

In this section, we study the case where firms invest cooperatively (denoted by c) in R&D. In the present case, firms avoid free-riding, as far as spillovers are internalized and as a result, the amounts invested in R&D and firms' profits are affected positively. However, unions' rent-extracting remains a determinant that discourages firms to invest in R&D.

Regardless the institutional level where wages are set, in the last stage of the game, firms 1 and 2 compete in a Cournot fashion in the product market. Output and employment are given by eq. (2).

We firstly consider the case where wages are set at the level of firms (structure D). Given q_i^* and q_j^*, firm-level unions set wages simultaneously and non-cooperatively so as to maximize their rents. Firm-level wages are given by eq. (4).

In the second stage of the game firms set cooperatively their R&D investments (x_i, x_j) so as to maximize their joint profits:

$$
\begin{aligned}
\underset{x_i, x_j}{Max\Pi} \quad = \quad & \frac{4\left[5\left(a - c - w_0\right) + x_i\left(7\delta - 2\right) + x_j\left(7 - 2\delta\right)\right]^2}{2025} \\
& + \frac{4\left[5\left(a - c - w_0\right) + x_i\left(7 - 2\delta\right) + x_j\left(7\delta - 2\right)\right]^2}{2025} - x_i^2 - x_j^2
\end{aligned}
\tag{20}
$$

The solution of first order conditions of eq. (20) gives symmetric R&D investments in case of a RJV in equilibrium:

$$
x_i^* = \frac{\left(4 + 4\delta\right)\left(a - c - w_0\right)}{77 - 8\delta - 4\delta^2}
\tag{21}
$$

Using (2), (4), (20) and (21) we find that when firms invest cooperatively (c) and wages are set at the level of firms (D structure), total R&D investment $\left(X_c^D\right)$, firm-level wages $\left(w_{ic}^D\right)$, total employment and quantity $\left(L_c^D\right)$ and firm i's profits $\left(\Pi_{ic}^D\right)$ are:

$$
X_c^D = \frac{\left(8 + 8\delta\right)\left(a - c - w_0\right)}{77 - 8\delta - 4\delta^2}
\tag{22}
$$

$$
w_{ic}^D = \frac{27\left(a - c\right) - 2w_0\left(-25 + 4\delta + 2\delta^2\right)}{-77 + 8\delta + 4\delta^2}
\tag{23}
$$

$$
L_c^D = \frac{36\left(a - c - w_0\right)}{77 - 8\delta - 4\delta^2}
\tag{24}
$$

$$
\Pi_{ic}^D = \frac{4\left(a - c - w_0\right)^2}{77 - 8\delta - 4\delta^2}
\tag{25}
$$

4.2 The case of one industry union

Considering a uniform wage, determined at the level of industry (C structure), employment and output are given by eq. (11).

In the third stage of the game, the central union maximizes the utility function, given by eq. (12), by setting the uniform wage given by eq. (13).

Finally, in the second stage of the game firms decide upon their R&D investments, so as to maximize their joint profits:

$$\underset{x_i, x_j}{Max\Pi} = \begin{array}{c} \frac{1}{144} \left[2 \left(a - c - w_0 \right) + x_i \left(7\delta - 5 \right) + x_j \left(7 - 5\delta \right) \right]^2 \\ + \frac{1}{144} \left[2 \left(a - c - w_0 \right) + x_i \left(7 - 5\delta \right) + x_j \left(7\delta - 5 \right) \right]^2 - x_i^2 - x_j^2 \end{array} \tag{26}$$

The optimal firm i's R&D investment in case of a RJV is given by:

$$x_i^* = \frac{\left(1 + \delta \right) \left(a - c - w_0 \right)}{35 - 2\delta - \delta^2} \tag{27}$$

Using (11), (13), (26) and (27) we find that when firms invest cooperatively (c) and a central union sets a uniform wage (C structure), total R&D investment $\left(X_c^C \right)$, industry wage $\left(w_c^D \right)$, total employment and quantity $\left(L_c^C \right)$ and firm i's profits $\left(\Pi_{ic}^C \right)$ are:

$$X_c^C = \frac{\left(2 + 2\delta \right) \left(a - c - w_0 \right)}{35 - 2\delta - \delta^2} \tag{28}$$

$$w_c^C = \frac{-18 \left(a - c \right) + w_0 \left(-17 + 2\delta + \delta^2 \right)}{-35 + 2\delta + \delta^2} \tag{29}$$

$$L_c^C = \frac{12 \left(a - c - w_0 \right)}{35 - 2\delta + \delta^2} \tag{30}$$

$$\Pi_{ic}^C = \frac{\left(a - c - w_0 \right)^2}{35 - 2\delta + \delta^2} \tag{31}$$

For the case of cooperative R&D investments, comparing results under a decentralised system of wage-setting (D), with results under a central union (C), we state the following proposition:

Proposition 2 *Total R&D investments, firms' profits and employment (wages) are always higher (lower) under a decentralised system of wage-setting, compared with a centralised one.*

According to the R&D investments, in case of a RJV, firms' competition is less fierce (compared with the case of non-cooperative investments). Firms invest cooperatively, so as to maximize their joint profits and as a result they internalize spillovers and avoid free-riding. As far as an industry union extracts higher rents $\left(w_c^C > w_c^D \right)$, investments are higher under the decentralized system of wage setting $\left(X_c^D > X_c^C \right)$, in line with the hold-up argument. Therefore, in

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this case, it is the level where wages are set that drives R&D investments and a central union leads to underinvestment always. In case of non-cooperative investments, it is the coexistence of free-riding and rent-extracting that drives firms' investments, while under a RJV, it is only the rent extracting, as far as firms internalize spillovers.

According to wages, employment, output and profits, the intuition behind the result goes exactly as in the case of non-cooperative R&D and thus it is omitted as it replicates the same procedure seen in Proposition 1. Note that the negative effects of a central union on employment, output and profits, found for the case of non-cooperation, hold for the case of a RJV as well, and that high unemployment benefits deter R&D investments, employment and output too. In figures 2a and 2b, we plot firm-level profits and total R&D investments for the case of a RJV.

Let us now try to unify our results according to the effects of the different levels of unionisation. We found that the effect of union level on R&D investments depends on whether spillovers are internalized or lead to free-riding. This result underlines the critical role of the interaction between the level where wages are set and the spillovers of R&D activities, not mentioned in the literature up to date, and goes against the conventional argument which predicts negative effects of unions per se. Although a central union may favour non-cooperative R&D investments, we find that it always reduces employment, output and profits for both non-cooperative and cooperative R&D investments as well. Additionally, rigidities in the labour market, such as high unemployment benefits, increase wages and hinder R&D investments, employment and output.

Comparing our results with these of other papers, we believe that our findings contribute to the literature because we reveal the critical role of the interaction between the level where wages are set and the R&D spillovers. According to R&D investments, Ulph and Ulph (1994, 1998) argue that underinvestment due to unions can be overturned under bargaining over wages and employment (Efficient Bargaining). However it is well established that Efficient Bargaining is rarely observed in firms' practice (see Booth, 1995, p.128) and additionally, they examine the case of firm-level unions solely. Calabuig and Gonzalez-Maestre (2002), show that firms overcome underinvestment under a central union only if the market size is small. In our case, it is the coexistence of the central union's pressure and weak free-riding that help firms to overcome underinvestment. Finally, Haucap and Wey (2004), in a tournament R&D setting, focus on innovation incentives without examining firms' R&D investment levels. Another contribution to the relevant literature it that we carry out a detailed analysis for the effects on investments, wages, employment and output caused by rigidities in the labour market, a crucial issue for the European economy.

5   Firms' incentives for R&D cooperation

In this section we investigate firms' strategies in the first stage of the game. We consider that R&D cooperation is allowed and we examine whether firms have
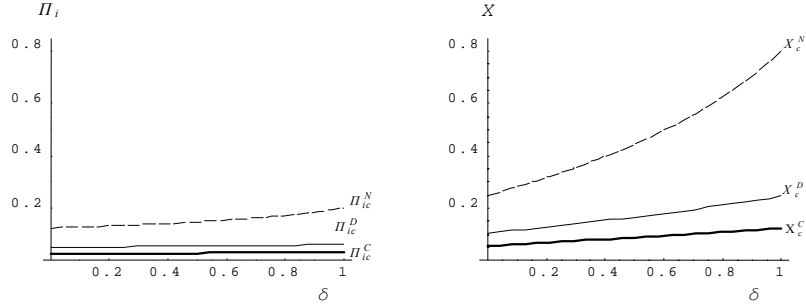
Figure 2: Cooperative R&D investments. 2a: Firm-level profits, in case of no unions $\left(\Pi_{ic}^N\right)$, two firm level unions $\left(\Pi_{ic}^D\right)$ and a central union $\left(\Pi_{ic}^C\right)$. 2b: Industry-wide R&D investments, in case of no unions $\left(X_c^N\right)$, two firm level unions $\left(X_c^D\right)$ and a central union $\left(X_c^C\right)$.

incentives to cooperate, for every level of wage-setting. Firm i has incentives to cooperate in R&D with firm j if each firm's profits under the RJV are higher than profits under non-cooperative investments. Thus, we answer the second question addressed in the introduction of this paper.

We begin our analysis with the case where wages are set at the level of firms. Firm i's profits under non-cooperative R&D are given by Π_{inc}^D, eq. (9) and under a RJV by Π_{ic}^D, eq. (24). We find that $\Pi_{ic}^D > \Pi_{inc}^D$, always holds (figure 3a). Given that R&D cooperation is profitable, firms have incentives to form a RJV. Furthermore, we find that a RJV improves R&D investments (figure 3b), wages, employment and output, if internalized spillovers exceed the critical rate $\delta_D = 0.29$.
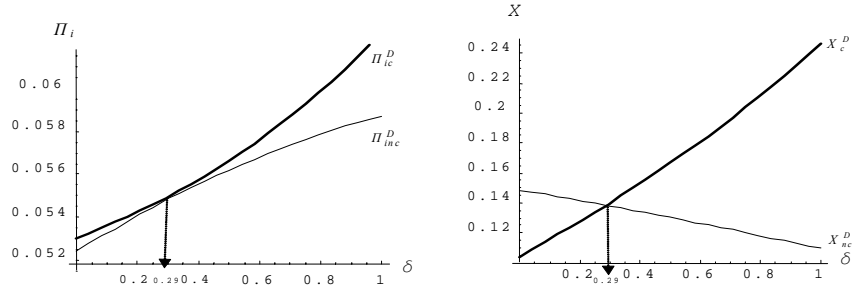

Figure 3: Firm level unions. 3a: Firm i's profits under strategic $\left(\Pi_{inc}^D\right)$ and cooperative $\left(\Pi_{ic}^D\right)$ R&D investments. 3b: Industry-wide R&D investments under strategic $\left(X_{nc}^D\right)$ and cooperative $\left(X_c^D\right)$ R&D investments.

We now consider the case of a uniform wage determined at the level of in-

dustry. In the same lines, given that firm i's profits under a RJV are always higher ($\Pi_{ic}^C > \Pi_{inc}^C$, figure 4a) firms will form a RJV. Moreover, R&D investments (figure 4b), wages, employment and output are higher under cooperative R&D investments, if internalized spillovers exceed the critical rate $\delta_C = 0.72$.
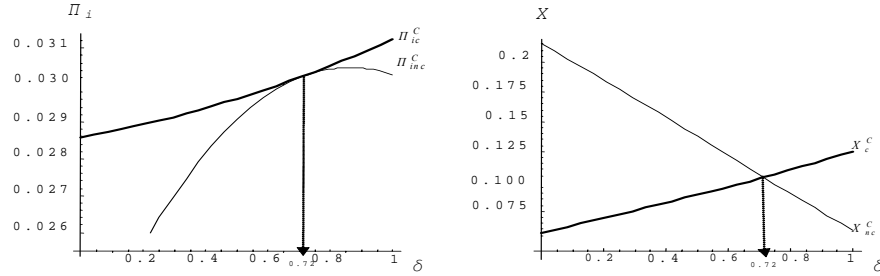

Figure 4: One industry union. 4a: Firm i's profits under strategic $\left(\Pi_{inc}^C\right)$ and cooperative $\left(\Pi_{ic}^C\right)$ R&D investments. 4b: Industry-wide R&D investments under strategic $\left(X_{nc}^C\right)$ and cooperative $\left(X_c^C\right)$ R&D investments.

According to firms incentives to form a RJV and its subsequent effects, we summarize our results in the next proposition:

Proposition 3 *(i) Firms have incentives to form a Research Joint Venture for cost reducing process innovations, regardless the institutional level of wage-setting. (ii) The effects of a Research Joint Venture on investments, wages, employment and output depend on the level of wage-setting.*

We proved that firms have incentives to form a RJV, regardless the level where wages are set. Intuitively, in case of non-cooperation, firms' competition in R&D and unions' rent-extracting behaviour may discourage firms to invest in R&D. On the contrary, by forming a RJV, firms act as a cartel in the R&D stage, they internalize spillovers and in turn, investments, employment, wages, output and profits increase sequenti.

We showed that a RJV, compared with non-cooperation, performs better in terms of R&D investments, wages, employment and output, whenever internalized spillovers exceed a critical rate. Our innovative argument is that the critical spillover rate is influenced by the level where wages are set. The minimum spillovers, that must be internalized, increase from $\delta_D = 0.29$ to $\delta_C = 0.72$, as we move from firm-level wage bargaining to a uniform wage determined at the level of industry.[20] Our analysis indicates that a central union deters investments, employment, wages and output increases, due to its stronger rent-extracting and its more intense 'rationally myopic' behaviour (Hirsch, 2004), compared

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[20]Consider an industry with $\delta = 0.4$. A RJV leads to investment, employment and wage and output increase, only if wages are set at the level of firms.

with firm-level unions. Therefore, we argue that a central union hinders dramatically the diffusion of the efficiency created by a RJV to consumers and employees.[21] The reason for that lays on the comparative shift of investments and the subsequent point of intersection of the R&D investment curves. If firms invest non-cooperatively, as spillovers increase, the decreasing rate of investment in case of industry wage-setting exceeds the decreasing rate of investment under firm-level wages $\left(\frac{dX_{nc}^D}{d\delta} < \frac{dX_{nc}^C}{d\delta}\right)$. Under a RJV, as spillovers increase, the increasing rate of investment under firm-level wage-setting exceeds the corresponding under an industry union $\left(\frac{dX_c^D}{d\delta} > \frac{dX_c^C}{d\delta}\right)$. Intuitively, the point of intersection between X_{nc}^D and X_c^D lays on the left of the point of intersection between X_{nc}^C and X_c^C.

By proving that firms have incentives to form a RJV always, what is more interesting is to compare their incentives under different levels of unionisation. For the case of firm-level unions, incentives for a RJV are given by $M^D = \Pi_{ic}^D - \Pi_{inc}^D$, while in case of a central union, incentives are given by $M^C = \Pi_{ic}^C - \Pi_{inc}^C$. Diagrammatically, M is the area between Π_{ic} and Π_{inc}, in figures 3a and 4a. Comparing M^D and M^C, we conclude on the following proposition:

Proposition 4 *Firms have stronger (weaker) incentives to form a Research Joint Venture, whenever they face an industry union (firm-level unions), if spillovers are low ($\delta < 0.55$), [high ($\delta > 0.55$)].*

In figure 5 we plot M^D and M^C. Although a RJV is profit-enhancing for firms, regardless the level where wages are set, it does not always lead to wage-increases for employees. Or else, although a RJV is profit-enhancing for firms, it has not always the same efficiency as a mechanism to overcome rent-extracting. Whenever internalized spillovers are low ($\delta < 0.55$), a RJV leads to wage-increase under firm-level unions $\left(w_{ic}^D > w_{inc}^D\right)$, if $\delta > 0.29$, while it never leads to wage-increase under one industry union. Thus, a RJV helps firms to overcome the rent-extracting exercised by two firm-level unions only if $\delta < 0.29$, while it always helps firms to overcome the corresponding by one industry union, as $w_c^C < w_{nc}^C$. The rent-extracting of a central union has been weakened more than the corresponding by two firm-level unions and incentives for a RJV are higher when firms face a central union $\left(M^C > M^D\right)$. On the contrary, whenever internalized spillovers are high ($\delta > 0.55$), a RJV always leads to wage-increases in case of firm-level unions, while it leads to wage-increases under a central union, only if $\delta > 0.72$. In this case, firms' profits increase through the RJV but employees capture higher rents too. Therefore, the RJV is mainly a mechanism that leads to wage-increases for employees, rather than a mechanism for firms to overcome rent-extracting and the incentives for a RJV are lower when firms face a central union $\left(M^C < M^D\right)$. The point of intersection $\left(M^C = M^D\right)$ is at

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[21]This argument can be crucial for policy suggestions, for the case of the European Union, given that although national and EU level R&D policies encourage RJVs consistently, centralised wage negotiations remain familiar in less R&D intensive countries (e.g. Spain and Greece) hindering their 'catch-up'.

$\delta = 0.55$. In general, we prove that whenever spillovers are low ($\delta < 0.55$), a RJV as a mechanism to overcome rent-extracting, operates more efficiently in case of an industry union, than for firm-level unions and incentives for cooperation are stronger for firms in industries with centralised systems of wage-setting.
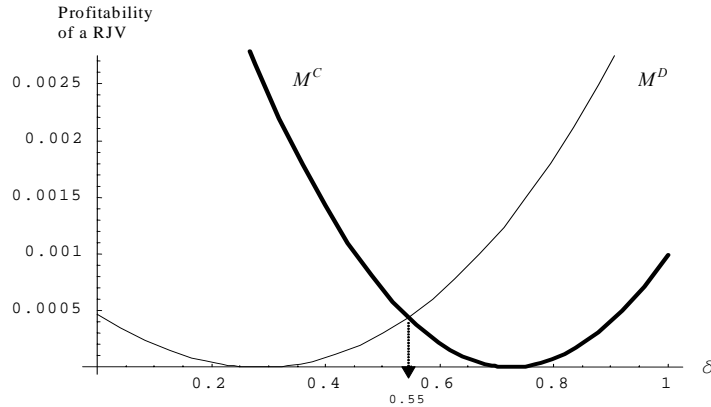

Figure 5: Incentives to form a RJV in case of two firm level unions $\left(M^D\right)$ and one industry union $\left(M^C\right)$.

6   Extensions

Our basic model is rather stylized, so it is natural to check the robustness of our results. Therefore, we need to explain how results may change when we extend our basic model in two different directions.

6.1   Bertrand competition[22]

The question addressed in this subsection is whether results demonstrated under Cournot competition, hold under price competition as well. We consider the case of two firms selling differentiated products. The timing of the game remains unchanged, except that in the last stage of the game, firms maximize their profits with respect to prices. The corresponding profit function for firm i, has the form:

$$
\begin{aligned}
\Pi_i\left(P_i, P_j, w_i, x_i, x_j, \delta, \theta\right) &= \left[Pi - \left(w_i + c - x_i - \delta x_j\right)\right] \times \\
&\quad \frac{\alpha\left(1 - \vartheta\right) + \vartheta P_j - P_i}{1 - \vartheta^2} - x_i^2
\end{aligned}
\tag{32}
$$

---

[22]Due to space limits, we briefly present our main findings. A detailed derivation of the results is available from the authors upon request.

It can be shown that results obtained in sections 3, 4 and 5, hold for the case of Bertrand competition as well. The reason is that while the nature of product market competition is altered, competition in prices does not alter the interactions between firms and unions that drive the results.

6.2   The general Right to Manage model

In the basic model, we assumed that unions unilaterally set the wages, while firms set employment and production levels. Therefore, we formalized rent-extracting in terms of institutional levels of bargaining. It is then natural to check whether our results still hold if we apply the general Right-to-Manage model, where firms do have bargaining power over wages. By doing so, we model unions' rent extracting both in terms of institutional levels of bargaining and in terms of distribution of bargaining power between firms and unions. This is an innovative modelling of unions' rent-extracting in the literature for the relationship between unionisation and innovative activity. In this literature, the rent-extracting of unions has been formalized either by the distribution of bargaining power between firms and firm-level unions, without examining different levels where bargaining over wage takes place (Ulph and Ulph, 1994, 1998; Tauman and Weiss, 1987), or by the institutional level where wages are set, without taking into account the distribution of bargaining power between firms and unions (Haucap and Wey, 2004; Calabuig and Gonzalez-Maestre, 2002).

In our case, if bargaining over wage takes place at the level of firms, we consider two firm-level unions endowed with the same bargaining power ($\beta_1 = \beta_2 = \beta_D$) and the general symmetric Nash bargain over wages, between union-firm pair i solves:

$$w_i = \arg\max \left\{ B_i = U_i^{\beta} \Pi_i^{1-\beta} \right\} \tag{33}$$

wher β is the union's Nash bargaining power and $0 \leq \beta \leq 1$.[23]

We find that if unions have no bargaining power ($\beta_D = 0$), the critical spillover rate is $\delta_D = 0.5$, while in case of firm-level monopoly unions ($\beta_D = 1$), $\delta_D = 0.29$. In case of a centralised system of bargaining, one industry union (with bargaining power β_C), bargains with industry's federation over a uniform wage. The federation acts so as to maximize overall industry's profits.[24] In a perfectly competitive labour market $\delta_C = 0.5$, and whenever a central union unilaterally sets the wage, $\delta_C = 0.72$. The critical spillover rate decreases from $\delta_C = 0.72$ to $\delta_C = 0.5$, as central unions' bargaining power decreases and labour market becomes more competitive.

As far as our results obtained under monopoly unions, remain qualitative robust under the general Right to Manage model, we show that it is mainly the institutional level of wage-setting, rather than the distribution of bargaining

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[23] Disagreement payoffs are assumed to be zero and w_0 for firms union(s) respectively.

[24] The case of firm-level bargaining over wages was analytically solved, while results for the case of bargaining between a central union and the federation were obtained after numerical simulations. A detailed file is available from the authors upon request.

power between firms and unions, that drives the results. This is an innovative argument too, given that, in the relevant literature the unions' rent extracting is *ex ante* modelled either in terms of bargaining power distribution with firm-level unions or in terms of different unionisation levels. We contribute to the relevant literature as far as examine the combination of the above points of view and we conclude that it is the level where wages are set that mainly drives the results.[25]

7   Welfare analysis

In this section we analyze how the organizational form and the externalities of R&D investments jointly with the level of wage-setting affect social welfare. In the literature for unions' effects on firms' R&D investments, this is the first time that a detailed welfare analysis is carried out and thus, we believe that our policy suggestions are more robust. We focus exclusively on the Cournot competition and we consider that there exists a regulator who can approve the formation of a RJV if it enhances social welfare.

The appropriate measure of welfare consists of three parts: consumers' surplus, firms' profits and employees' utility. Thus, social welfare can be defined as:

$$SW_A^B = \frac{1}{2} \left(Q_A^B \right)^2 + 2\Pi_A^B + 2w_A^B L_A^B, A = nc, c, B = D, C \tag{34}$$

$\frac{1}{2} \left(Q_A^B \right)^2$ indicates consumers' surplus, $2\Pi_A^B$ indicates overall industry profits and $2w_A^B L_A^B$ indicates overall unions' utility.

We have two alternative organizational forms of R&D activities (firms do not cooperate: nc, firms cooperate: c) and workers are organized either in firm-level unions (D) or in a central union (C). According to the social welfare (SW), four possible cases arise:

$$SW_{nc}^D = \frac{4 \left(13783 + 224\delta - 32\delta^2 \right) \left(a - c - w_0 \right)^2}{\left(377 - 20\delta + 8\delta^2 \right)^2} \tag{35}$$

$$SW_{nc}^C = \frac{2 \left(671 + 70\delta - 25\delta^2 \right) \left(a - c - w_0 \right)^2}{\left(65 - 2\delta + 5\delta^2 \right)^2} \tag{36}$$

$$SW_c^D = \frac{4 \left(559 - 16\delta - 8\delta^2 \right) \left(a - c - w_0 \right)^2}{\left(-77 + 8\delta + 4\delta^2 \right)^2} \tag{37}$$

$$SW_c^C = \frac{2 \left(179 - 2\delta - \delta^2 \right) \left(a - c - w_0 \right)^2}{\left(-35 + 2\delta + \delta^2 \right)^2} \tag{38}$$

---

[25] We have only investigated the case of Cournot competition, but we believe that our results will be valid in case of Bertrand competition as well.

We find that $SW_{nc}^D > SW_{nc}^C$ and $SW_c^D > SW_c^C$ always hold, for the case of non-cooperative and cooperative R&D, respectively. Therefore, we find that a centralised system of wage-setting leads to a consistent depression in social welfare, for both organizational forms of R&D investments. The intuition behind this result is quite simple: social welfare is the sum of consumers' surplus, firms' profits and employees' utility. Firms' profits and consumers' surplus are always higher under a decentralised system of wage-setting. In contrast, employees' utility is always higher under a centralised system of wage-setting. But, the sum of firms' profits and consumers' surplus overcomes the central union's depression in social welfare. Results are presented diagrammatically in figure 6.

We now turn to the core issue of the social welfare analysis. Should the regulator approve the RJV formation? In order to answer this question, we compare, for every level of wage-setting, social welfare under strategic R&D investments with welfare in case of a RJV and we summarize our findings in the following proposition:

Proposition 5 *Under a decentralised (centralised) system of wage-setting, the regulator should approve the Research Joint Venture formation if the spillover rate is $\delta_D > 0.29$ ($\delta_C > 0.72$).*

The economic rationale behind this result lays in the analysis carried out in section 5, where we proved that a central union deters the diffusion of the efficiency created by a RJV to consumers and employees. Formally speaking, firms' profits are always higher under cooperative R&D investments, but unions' utility and consumers' surplus are higher only if $\delta_D > 0.29$ ($\delta_C > 0.72$) under a decentralised system of wage-setting (a centralised system), compared with non-cooperative R&D investments. We present our results in figure 6.
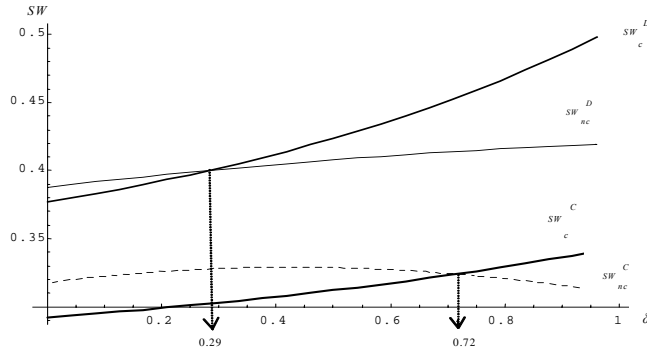

Figure 6: Social welfare under strategic and cooperative R&D investments, in case of firm-level and industry-wide wages.

We show that the level where wages are set should affect regulators' decisions according to the approval of a RJV. Our analysis also reveals that although a

RJV is always profitable for firms, it is not always preferable for regulators. In industries with firm-level wage-setting, firms' and regulators' preferences will be aligned if internalized spillovers exceed $\delta > 0.29$, while the corresponding threshold for industries with a uniform wage is at $\delta > 0.72$. This result underlines the difficulties for the alignment between firms' and regulators' preferences, caused by a centralised system of bargaining. This approach for the distortion in social welfare by industry unions, is also innovative in the literature.

Based on the above analysis, some directions for policy implications come directly. First of all, taking as a fact the depressing effects of a central union on social welfare, our first policy implication indicates that policy-makers should extend the antitrust rules to labour markets and move towards the decentralisation of wage bargaining in R&D intensive industries.[26] It is easily observable in figure 6 that the decentralisation of wage bargaining leads to enhanced social welfare in cases of non-cooperative and cooperative R&D investments. Additionally, we have already assumed that the unemployment benefit w_0, set by the regulator, can be an instrument for labour market policy and so far analysis has showed that unemployment benefits strengthen unions' rent-extracting potential and deter investments and employment increases. Therefore, we further suggest the decrease of the unemployment benefits in R&D intensive industries, in order to increase investments and employment.

Our policy-mix also contains the encouragement of RJVs, as far as the it is the combination of the above labour market policies together with the formation of RJVs, that leads to enhanced social welfare, given that a minimum rate of spillovers ($\delta > 0.29$) are internalized. Through our integrated policy-mix, policy-makers can overturn not only rent-extracting (through decentralising wage bargaining) but also free-riding (through encouraging RJVs), and this is not only a novel aspect in the relevant literature, but also a straightforward applicable policy. Especially for the case of European Union, given the wide centralisation of wage-bargaining between firms and unions and the asymmetries across Member States R&D policies as well, we suggest that the above policy-mix can be an effective framework for integrated labour markets and R&D policies which will sufficiently increase European competitiveness.

8   Conclusions

This paper contributes to the literature for the relationship between unionisation and innovative activity. We incorporated R&D spillovers and the RJV potential and we proved that the effect of the level of unionisation on R&D investments depends on whether spillovers are internalized or lead to free-riding, a result that goes against the conventional argument for the negative effects of unions per se. We further proved that although an industry union may strengthen

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[26]In line with Haucap and Wey (2004), the extension of antitrust rules to labour markets would mean that the formation of industry unions and collective wage agreements should not be allowed due to their monopolisation effects. However, although in Haucap and Wey (2004), this suggestion is rather intuitive, we prove its necessity.

firms' incentives to form a RJV, rigidities in the labour market, such as an industry and/or high unemployment benefits, hinder employment and output. We also found that a central union's 'rationally myopic' behaviour deters the diffusion of the efficiency created by a RJV to consumers and employees and hinders the alignment between firms' and regulators' preferences according to the formation of a RJV. Therefore, we suggest that extending antitrust rules to labour markets, reducing unemployment benefits and encouraging RJVs, can be an integrated framework to improve both market performance and consumers surplus as well.

Finally, we hope that our results could guide future empirical research on the "R&D investments in unionised industries" literature, given the inconclusive received empirical results. We suggest that an empirical test should begin with a detailed study for the discrimination in the data material between industries with firm- and central-level unions, low and high R&D spillovers, RJVs and non-cooperative forms of R&D investments. For industries with low R&D spillovers and non-cooperative forms of R&D investments, if one combines R&D investments under industry unions with investments under firm-level unions, one might find that in the former case investments are higher. In contrast, for industries with cooperative forms of R&D investments, one might find opposite results.

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