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Endogenous codetermination

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This research introduces endogenous codetermination in a Cournot duopoly. Unlike the received literature (Kraft, 1998), this work assumes that firms bargain with their own union bargaining units under codetermination if and only if they can choose an ad hoc bargaining effort by maximising profits (three-stage non-cooperative game). There are remarkable differences compared with the main findings of the exogenous codetermination literature. Indeed, there may exist asymmetric multiple (Pareto efficient) Nash equilibria in pure strategies. Mandatory codetermination, therefore, is Pareto worsening. Each firm can then use the union bargaining power as a strategic device in a Cournot setting.

1 | INTRODUCTION

This research offers an alternative point of view about the institution of codetermination and speculates in this direction by introducing endogenous codetermination in a game theoretic setting framed in a strategic competitive market (duopoly). In a nutshell, codetermination works through a supervisory board including workers' representatives, and the key elements are represented by the composition of and the role played in the firm's governance by the supervisory board (with its rules).

Since the pioneering works of McCain (1980) and Kraft (1998), there has been increasing attention by the theoretical (Fanti et al., 2018; Kraft, 2001; Kraft et al., 2011) and empirical (FitzRoy & Kraft, 1993, 2005; Gorton & Schmid, 2004; Kraft, 2018) literatures on the effects of codetermination on labour productivity and the output market. McCain (1980) was the first in providing a detailed contribution about the theoretical effects of codetermination in the industrial economics literature, whereas Kraft (1998) built on a Cournot duopoly showing that codetermination can emerge endogenously in a strategic competitive market with homogeneous goods where players (firms) choose between profit maximisation or being bargainers under codetermination. This outcome, however, is Pareto inefficient as there is a conflict between self-interest and the mutual benefit to undertake codetermination. One of the main characteristics of the institution of codetermination is that employment (and therefore production) is chosen jointly by a supervisory board composed of employer and employee representatives who bargain until a certain level of employment (production) is agreed upon. Codetermination is a relevant feature of the German industry though comprehensive legislation on board-level representation can be found in several countries, such as Austria, Denmark, Finland, France, Luxembourg, the Netherlands, Norway and Sweden (Schulten & Zagelmeyer, 1998). In Germany, the Codetermination Act of 1976 allows the number of workers' representatives ranging from one third to one half of the seats in the supervisory board depending on the number of employees (e.g., firms employing more than 2000 employees should recognise workers as being represented by one half of the seats).

The history of the institution of codetermination in Germany is interesting and deserves a summary. The first attempt to give birth to what we now know as 'Codetermination' dates to 1848

(Constituent National Assembly, *Pauluskirche*, Frankfurt), with the first attempt to requesting and setting up factory committees with participation rights to improve employees' working and living conditions. At a nation-wide level, however, such an attempt failed essentially because of the obstructions on the part of employers that did not want to see their own decision-making power (and profits) being eroded. Nonetheless, this opposing pressure did not prevent the voluntary establishing of factory committees in some specific cases. Then, the Act on Civilian War Work Service (*Gesetz über den Väterlandischen Hilfsdienst*) was introduced during WWI (1916) with the aim of providing the basis for establishing workers' committees in industries relevant for the war effort, especially in firms with more than 50 employees. From 1919 to 1922 (the Weimar Constitution Art. 165, 1919; the Works Council Act, *Betriebsrätegesetz*, 1920; the Act on the Representation of Works Council Members in the Supervisory Boards, 1922), there was an impetus for a steadily growing legislation in workers' rights and work regulations (e.g., the employees' representatives voting right on the supervisory boards), effectively providing the basis for future codetermination. This growth path was abruptly halted during the Nazi regime, where the Nazi party decided to remove—among other things—the workers participation right on the supervisory board (Act to Regulate National Work, *Gesetz zur Ordnung der nationalen Arbeit*, 1934). There was, however, a new radical change during the Allied occupation of Germany (1945) through a support of a democratic view of industrial policy and the strengthening of union activities, turning to a pre-Nazi view about workers' rights and participation. In this regard, the example (followed by other industries) is given by agreement on parity codetermination between employers and employees representatives in the iron and steel industry in the British Sector (1947). A milestone in the history of modern codetermination is represented by the Act on Codetermination (1951) and the Work Constitution Act (*Betriebsverfassungsgesetz*, 1952). The former introduced parity codetermination on the supervisory boards in the coal, iron and steel industry. The latter followed the former and established codetermination for private (large and medium sized) firms through their own work councils (one third of the employees' representation on the supervisory boards). From 1965 to 1974, there were several laws expanding codetermination both in public and private sectors at establishment level. This development path led to the building of to the main pillar of codetermination: the Codetermination Act of 1976, establishing codetermination at firm level in all industries with more than 2000 employees by also including one managerial employee seat in the board. There have been other future attempts to go further in the developments of the rules governing codetermination but with minor changes to the existing legislation. The most relevant exception is represented by the Amendment New Third Part Act (*Drittelbeteiligungsgesetz*, 2004) with the aim to update the Works Constitution Act of 1952 about the membership of the supervisory board.

To sum up, there are currently three different relevant frameworks in the codetermination legislation. Codetermination is working through a supervisory board including employers and employees' representatives, and it is applied:

1. in the coal, iron and steel industry with a parity between workers and shareholders representatives in the board (since 1951);
2. in firms with more than 500 employees (all industries) where workers have one third of the seats in the board and shareholders the remaining two third (since 1952 with small changes since 2004);
3. in the firms with more 2000 employees (all industries), with a parity between workers and shareholders representatives in the board (since 1976).

The oversimplified duopoly model of Kraft (1998)—as well as those of the subsequent oligopolistic literature—translated the main features of the Codetermination Act of 1976 in a theoretical framework dealing with strategic competition, where the bargaining owner-union over employment (production) was built on by assuming that the bargaining effort of the negotiating parties is an exogenous variable.[1] Differently, the approach used here suggests that firms can choose to bargain employment with a decentralised trade union under codetermination if and only if they can maximise profits by choosing an ad-hoc bargaining effort (endogenous codetermination). Unlike the case of exogenous codetermination, the present work considers a three-stage (instead of a two-stage) non-cooperative game with complete information. At the *codetermination stage* (Stage 1), firms play the codetermination decision game. At the *union-strength stage* (Stage 2), the owner-union bargaining occurs if and only if there exists a profit-maximising bargaining effort. At the *bargaining-market stage* (Stage 3), there are two options: firms can opt for choosing unilaterally the quantity to be produced if they are profit maximisers or, alternatively, they can bargain employment with their own decentralised trade union under codetermination. This exercise is presented for the case of liner costs (constant returns to labour), as in Kraft (1998) and extended to quadratic costs (decreasing returns to labour). In the former case, results show that both firms have an incentive to be codetermined in the market (prisoner's dilemma) only when products are highly differentiated. Differently, when products are poorly differentiated there are mixed multiple Nash equilibria where only one firm endogenously chooses codetermination (this result holds also when products tend to be homogeneous). This outcome is Pareto efficient (chicken game), so that mandatory codetermination is Pareto worsening. Therefore, in the case of constant average and marginal costs (technology with constant returns to labour), product differentiation drives the main results. In the latter case, the endogenous bargaining strength depends on the wage rate bargained at the centralised level. If the wage is sufficiently small, the codetermination game becomes a chicken game with two Pareto efficient Nash equilibria according to which only one firm chooses to be codetermined. If the wage is sufficiently large, the outcome is a prisoner's dilemma where both firms choose to be codetermined. Therefore, in the case of quadratic costs (technology with decreasing returns to labour), that is convex increasing marginal costs, the wage drives the main results.

Our findings provide a rationale for the emergence of a prisoner's dilemma, as was also point out in the original work of Kraft (1998) with exogenous codetermination, and a different outcome (anti-coordination game) where only one firm chooses to voluntarily set codetermination and the rival continues to be a profit maximiser. These findings have policy consequences regarding mandatory versus voluntary codetermination. The work complements Fanti and Gori (2019), who studied a model of exogenous and endogenous codetermination in a Bertrand rivalry setting with network consumption externalities, showing that the emergence of voluntary codetermination is network depending in that case. Differently, this work points out that endogenous codetermination emerges also in a standard non-network Cournot industry with horizontal product differentiation.

The Industrial Organisation (IO) literature has so far identified the managerial delegation contract as a 'strategic device' that selfish firms can use for their own purposes. This article identifies codetermination as another instrument that firms can use endogenously and strategically to maximise profits: the union bargaining power represents a new strategic device that firms can use in strategic competitive markets.

The rest of the article proceeds as follows. Section 2 builds on a game played by strategic competitive duopoly firms in a Cournot market with a differentiated products and linear costs, and then discusses the main results. Section 3 extends the model to the case of quadratic costs. Section 4 outlines the main conclusions.

2 | A COURNOT DUOPOLY WITH ENDOGENOUS CODETERMINATION

Consider an industry where two firms produce heterogeneous goods in a strategic competitive Cournot setting. Consumers are identical and their preferences are characterised by a quadratic utility function generating an inverse (market) demand given by $p_i = 1 - q_i - dq_j$, where $q_i \geq 0$ and $q_j \geq 0$ denote the quantities produced by firm i and firm j ($i = \{1,2\}$, $i \neq j$), respectively, $p_i \geq 0$ is the price of product of variety i, and $-1 \leq d \leq 1$ represents the degree of horizontal product differentiation (Singh & Vives, 1984). Products of varieties i and j are perfect substitutes if $d = 1$. They are perceived as perfect complements if $d = -1$. The case $0 < d < 1$ implies imperfect substitutability. Instead, the case $-1 < d < 0$ implies imperfect complementarity. The generic firm i ($i = \{1,2\}$, $i \neq j$) produces with a production function displaying constant marginal returns to labour $q_i = L_i$, where L_i represents the labour force employed by the firm. The average (and marginal) cost is $0 \leq w < 1$, which is the same for every firm, and represents the cost per unit of labour hired by the firm. Therefore, firm i's cost and profit functions are respectively given by the expressions $C_i = w\,q_i$ and $\Pi_i = (p_i - w)\,q_i$.

Since Kraft (1998), the established literature on codetermination assumes that employer and employee representatives' bargain at the firm level to choose employment (and output production). In doing this, players considered the wage as given (as it was bargained at the centralised or nation-wide level). One of the drawbacks of the original approach of Kraft (1998) and the subsequent literature lies in assuming that the bargaining effort is taken exogenously, so that a codetermined firm can bargain with its own trade union in a decentralised bargaining with no opportunities to intervene to adjust the bargaining effort by adapting it based on the owner's will. A possible way to overcome this concern based on this line of reasoning lies in allowing owners to bargain with a trade union at the decentralised level under codetermination if (and only if) there exists a profit-maximising bargaining effort. In the actual world, different trade unions may bargain with a different bargaining strength, that is, there can be a continuum of heterogeneous unions, which may not necessarily be appreciated by the corresponding firm in the bargaining process. By accounting for this heterogeneity, the present work extends the IO literature on codetermination and speculates on the opportunity for a firm to bargain or not to bargain under codetermination being aware of each union's characteristics and then choosing to be involved in a bargaining on employment (production) at a decentralised level if and only if the owner is able to set an ad-hoc (profit-maximising) bargaining effort. Then, each firm can select the board of directors (possibly including employee representatives) choosing the amount output to be sold in the product market. In other words, each owner maximises profits at the second stage of the game by choosing an ad hoc bargaining effort corresponding to which there is a given number of employee representatives in the supervisory board.

There exist heterogeneous decentralised trade unions distinguished based on their relative attitude to bargain in the labour market. This effort is described by a number that belongs to a continuum of values between 0 and 1. In this context, do firms have an incentive not to bargain under codetermination, or—alternatively—is it convenient to bargain with a low-effort union bargaining unit? The answer to these questions is not clear cut and depends on the strategic interaction of players playing a non-cooperative endogenous codetermination game.

The logical timing of the events is the following. At the *codetermination stage* (Stage 1), firms play the codetermination decision game. At the *union-strength stage* (Stage 2), the owner-union bargaining occurs if and only if there exists a profit-maximising bargaining effort. At the *bargaining-market stage* (Stage 3), there are two options, that is, firms can opt for choosing unilaterally the quantity to be produced if they are profit maximisers or, alternatively, they can bargain the amount of output production with their own decentralised trade union under codetermination. The game is solved through backward induction.

Firm i aims at maximising profits $\Pi_i = (1 - q_i - dq_j - w)q_i$ by choosing product of variety q_i. The type-i union bargaining unit (i.e., the union belonging to firm i) aims at maximising its own utility $Z_i = (w - w^\circ)L_i$ with respect to employment L_i, where $w^\circ = 0$ is the reservation wage. Knowing that technology implies that one unit of labour is transformed into one unit of output ($L_i = q_i$), the utility of trade union of type i becomes $Z_i = w\,q_i$. The firm-union Nash bargaining process allows the owner (resp. union) to bargain q_i with an effort $0 < \beta_i \leq 1$ (resp. $1 - \beta_i$). Therefore, the Nash bargaining function is $\mathrm{N}_i = \Pi_i^{\beta_i} Z_i^{1-\beta_i}$. By using the expressions of profits and union's utility, this function takes the form $\mathrm{N}_i = \left[(1-q_i-dq_j-w)q_i\right]^{\beta_i}(wq_i)^{1-\beta_i}$, which should be maximised with respect to q_i.

2.1 | The symmetric subgame of endogenous codetermination (B/B)

If both firms are codetermined ($\beta_i < 1$, $i=\{1,2\}$, $i \neq j$), the output that firm i will produce at the third stage of the game will be determined by choosing q_i to maximise N_i. Therefore, one gets:

$$\frac{\partial \mathrm{N}_i}{\partial q_i} = 0 \Leftrightarrow q_i(q_j) = \frac{1-w-dq_j}{1+\beta_i}, \tag{1}$$

representing the reaction function of player i, whose dependence on q_j, d and β_i is standard. By using the expressions for players i and j from Equation 1, one obtains the equilibrium outcome produced by firm i at the bargaining market stage of the game as a function of the bargaining efforts of firm i and firm j, that is,

$$\bar{q}_i^{B/B}(\beta_i,\beta_j) = \frac{(1-w)(1-d+\beta_j)}{1-d^2+\beta_i+\beta_j+\beta_i\beta_j}, \tag{2}$$

where B/B denotes that both players are bargainers under codetermination. Equilibrium profits of firm i as a function of the bargaining efforts of both firms are given by

$$\bar{\Pi}_i^{B/B}(\beta_i,\beta_j) = \frac{\beta_i(1-w)^2(1-d+\beta_j)^2}{\left(1-d^2+\beta_i+\beta_j+\beta_i\beta_j\right)^2}. \tag{3}$$

At the second stage of the game, the firm-union i bargaining process under codetermination occurs if and only if there exists a profit-maximising bargaining power for firm i. Therefore, the maximisation of the expression in Equation 3 with respect to β_i by firm i allows to get the reaction bargaining functions at the union-strength stage, that is,

$$\frac{\partial \bar{\Pi}_i^{B/B}}{\partial \beta_i} = 0 \Leftrightarrow \beta_i(\beta_j) = \frac{1-d^2+\beta_j}{1+\beta_j}, \tag{4}$$

from which an increase in the bargaining power of the rival (firm j) induces firm i to increase its bargaining effort (i.e., the bargaining effort of the firms are strategic complements). This is because each firm wants to increase its own outcome (profit) as much as possible at the expense of its rival by increasing its own bargaining power, but no firm wants to lose unilaterally the opportunity to increase its own profits if the rival increases its bargaining power. An increase in the degree of product differentiation ($d\downarrow$) allows each firm to increase its own market share at the expense of the rival's share in the market for the product of its own variety. This eventually contributes to increase firm profits and the bargaining effort of every firm in the Nash bargaining eventually shifting upward the reaction bargaining functions and the second-stage equilibrium bargaining effort. Indeed, from the system of reaction-bargaining-functions of firms i and j, one can get the following symmetric equilibrium bargaining effort:

$$\beta_i^{B/B} = \sqrt{1-d^2} < 1. \tag{5}$$

Equation 5 defines a simple rule for the optimal or endogenous codetermination in the symmetric subgame B/B, showing that an increase in the degree of product differentiation ($d\downarrow$), allowing a firm to increase the market power and reduce the degree of competition in the market, is such that each firm maximises its own profits by bargaining with increasingly less aggressive trade unions ($\beta\uparrow$). This is because each firm tends to reduce production and they are unwilling to allow employment increases to its own union bargaining unit. As products tend to be perceived as homogeneous by customers ($d=1$), the more convenient is for firms to do not bargain employment (and production) with trade unions. When products are perfectly homogeneous, a firm becomes labour managed, and profits are zero. We can define this scenario as the paradox of voluntary (endogenous) codetermination. If one firm competes with a rival in a context where both agree to bargain employment with their own decentralised union under endogenous codetermination, and products are perceived as homogeneous, each of them has a unilateral incentive to increase production and its market share at the expense of the rival thereby accepting to increase the bargaining power of its own union-bargaining unit as a profit maximising strategy at the second stage of the game. However, as the union bargaining power ($1-\beta_i^{B/B}$) at the equilibrium increase with d, then the competition on the choice of the quantity to be produced and sell in the output market with workers' representatives erodes firm profits and leads to the zero profit condition when products are homogeneous, that is, the firm becomes a labour-managed entity in that case.[2] The owner, therefore, uses the trade union under endogenous codetermination as the manager under managerial delegation. For example, regardless of the Nash equilibria of the game, it should be pinpointed that the bargaining power is a strategic variable acting similarly to the bonus owners set to managers at the bonus stage in managerial firms as they produce more than under profit maximisation. Therefore, increasing the union's bargaining power on the supervisory board works out qualitatively in the direction of increasing employment and production.

If products are differentiated, each firm can benefit from a higher market share than when products are homogeneous (regardless of the strength of the degree of competition with the rival in the product market). Therefore, to gain additional market share in the market for its own product, each owner does not need to increase production further up to its maximum threshold, leaving the choice of employment entirely to its own union bargaining unit. Differently, if products are homogeneous, each firm has an incentive to produce up the point in which the demand for the product of its own variety and the supply intersect each other (depending of course on the choice of the rival). In this case, therefore, each firm has an incentive to be bargainer under codetermination and leave the choice of employment *entirely* to its own decentralised union bargaining unit becoming a labour managed firm (we will see later, however, that this strategy will never emerge at the equilibrium).

By substituting out the expression in Equation 5 into Equation 3, one gets the equilibrium value of profits of firm i in the case both firms are codetermined under endogenous codetermination, which are given by

$$\Pi_i^{B/B} = \frac{(1-w)^2\sqrt{1-d^2}\left(1-d+\sqrt{1-d^2}\right)^2}{4\left(1-d^2+\sqrt{1-d^2}\right)^2}. \tag{6}$$

2.2 | The symmetric subgame of profit maximisation (PM/PM)

If both firms are profit maximisers ($\beta_i = \beta_j = 1$, $i = \{1,2\}$, and $i \neq j$), the output that firm i should produce is chosen by the owner of the firm. Therefore, the maximisation of N_i with respect to q_i at the market stage of the game gives the reaction function of firm i:

$$\frac{\partial \mathrm{N}_i}{\partial q_i} = 0 \Leftrightarrow q_i(q_j) = \frac{1-w-dq_j}{2}. \tag{7}$$

By using the expression in Equation 7 together with the corresponding counterpart for firm j, we get the symmetric equilibrium outcome produced by firm i:

$$q_i^{PM/PM} = \frac{1-w}{2+d}, \tag{8}$$

where PM/PM denotes that both firms are profit maximising. Therefore, equilibrium profits of firm i are given by

$$\Pi_i^{PM/PM} = \frac{(1-w)^2}{(2+d)^2}. \tag{9}$$

2.3 | The asymmetric subgame in which only one firm is codetermined (B/PM)

The asymmetric subgame implies that firm i is codetermined ($\beta_i < 1$) and firm j is profit maximiser ($\beta_j = 1$), and vice versa. The firm-union bargaining i and profit maximisation by firm j at the third stage of the game implies

$$\frac{\partial \mathrm{N}_i}{\partial q_i} = 0 \Leftrightarrow q_i(q_j) = \frac{1-w-dq_j}{1+\beta_i}, \tag{10}$$

and

$$\frac{\partial \mathrm{N}_j}{\partial q_j} = 0 \Leftrightarrow q_j(q_i) = \frac{1-w-dq_i}{2}. \tag{11}$$

By using Equations 10 and 11, one gets the expressions of the quantities produced by the codetermined firm i and the profit maximising firm j as a function of the bargaining effort β_i along with the corresponding profit functions, that is,

$$\bar{q}_i^{B/PM} = \frac{(1-w)(2-d)}{2-d^2+2\beta_i}, \tag{12}$$

$$\bar{q}_j^{B/PM} = \frac{(1-w)(1-d+\beta_i)}{2-d^2+2\beta_i}, \tag{13}$$

$$\bar{\Pi}_i^{B/PM} = \frac{(1-w)^2(2-d)^2}{\left(2-d^2+2\beta_i\right)^2}, \tag{14}$$

and

$$\bar{\Pi}_j^{B/PM} = \frac{(1-w)^2(1-d+\beta_i)^2}{\left(2-d^2+2\beta_i\right)^2}. \tag{15}$$

At Stage 2, the bargaining between firm i and union i occurs if and only if there exists a profit-maximising bargaining effort. Therefore, the maximisation of the expression in Equation 14 with respect to β_i allows to get the following optimal bargaining effort in the case of asymmetric behaviour:

$$\frac{\partial \bar{\Pi}_i^{B/PM}}{\partial \beta_i} = 0 \Leftrightarrow \beta_i^{B/PM} = 1 - \frac{1}{2}d^2 < 1. \tag{16}$$

A direct comparison between Equations 5 and 16 under the assumption of perfect substitutability ($d = 1$) shows that when only one firm chooses to be bargainer under codetermination, it will find it optimal to set its own bargaining power over employment at 50%, whereas if both firms choose to endogenously codetermine employment with their own union bargaining units, 'the working of the strategic substitution game' will lead each of them to leave employment be set entirely by unions (de facto becoming a labour-managed firm).

By substituting out the expression in Equation 16 into Equations 14 and 15, one gets the equilibrium value of profits of the codetermined firm i and profit maximising firm j, which are respectively given by

$$\Pi_i^{B/PM} = \frac{(1-w)^2(2-d)^2}{8\left(2-d^2\right)}, \tag{17}$$

and

$$\Pi_j^{B/PM} = \frac{(1-w)^2\left(4-d^2-2d\right)^2}{16\left(2-d^2\right)^2}. \qquad (18)$$

$$\Delta_a = \Pi_i^{B/PM} - \Pi_i^{PM/PM} = \frac{(1-w)^2 d^4}{8(2+d)^2\left(2-d^2\right)} > 0,$$

$$\Delta_b = \Pi_i^{PM/B} - \Pi_i^{B/B} = \\ = \frac{(1-w)^2}{16\left(2-d^2\right)^2\left(1-d^2+\sqrt{1-d^2}\right)^2} \times \\ \times \left[d^8 - 4d^7 + d^6 + 12d^5 - 10d^4 - 8d^3 + 8d^2 - 4\sqrt[3]{1-d^2}\left(2-d^2\right)^2 - \sqrt{1-d^2}\left(6d^6 - 22d^4 - 8d^3 + 40d^2 - 16\right)\right],$$

and

$$\Delta_c = \Pi_i^{PM/PM} - \Pi_i^{B/B} = \frac{(1-w)^2\left[2d^2(1+d)\left(1-d^2\right) - \sqrt[3]{1-d^2}(2+d)^2 - \left(d^4 + 2d^3 + 5d^2 - 4d - 4\right)\sqrt{1-d^2}\right]}{4(2+d)^2\left(1-d^2+\sqrt{1-d^2}\right)^2} > 0.$$

2.4 | Nash equilibria and discussion under constant average and marginal costs

The equilibrium outcomes of the endogenous codetermination game are summarised in Table 1 (optimal bargaining effort) and Table 2 (profits) according to the strategies available to each firm.

The outcomes of the endogenous codetermination game (at Stage 1) are summarised in Proposition 1.

Proposition 1. (1) If $-1 < d < 0.76913$, then (B,B) is the unique Pareto inefficient SPNE of the game (prisoner's dilemma). (2) If $0.76913 < d \leq 1$, then (B,PM) and (PM,B) are two pure-strategy Pareto efficient Nash equilibria (anti-coordination game).

Proof. Profit differentials Δ_a, Δ_b and Δ_c are the following:

TABLE 1 Optimal bargaining effort under B and PM

	Firm 2	
Firm 1	**PM**	**B**
PM	1,1	$1, 1-\frac{1}{2}d^2$
B	$1-\frac{1}{2}d^2, 1$	$\sqrt{1-d^2}, \sqrt{1-d^2}$

The sign of Δ_b changes depending on the relative size of d. Then, we have that (1) if $-1 < d < 0.76913$, then $\Delta_a > 0$, $\Delta_b < 0$ and $\Delta_c > 0$ and (2) if $0.76913 < d < 1$, then $\Delta_a > 0$, $\Delta_b > 0$ and $\Delta_c > 0$. **Q.E.D.**

When firms choose optimally the bargaining effort, the results of the original work of Kraft (1998) hold only when products are sufficiently differentiated (Table 3, $d = 0.5$). In that case, B is a dominant strategy, but the Nash equilibrium (B,B) is suboptimal as firms have a joint incentive to coordinate towards PM, but each of them has a unilateral incentive to play B. The optimal bargaining effort of the firm implies that almost 20% of the seats on the supervisory board are left to employees' representatives. Definitively, when products are sufficiently differentiated, firms' profits tend to be higher than when products tend to be homogeneous and this, in turn, implies that the market share (in the markets for the relevant products) of each firm tends to increase. This makes firms willing to bargain employment with the union (which in turn also increases output) accepting a reduction in their own bargaining power as firms suffer less from competition in the product market in that case, and the equilibrium bargaining power of the union is higher than when the degree of product differentiation is lower, and products tend to be highly substituted. So each rational and selfish firm has a dominant strategy: B, allowing to obtain the best outcome regardless of the rival's choice. Given the payoff matrix, in fact, no one is interested in playing PM if the rival plays PM, because everyone prefers to unilaterally accept endogenous

TABLE 2 Payoff matrix (profits) under B and PM

	Firm 2	
Firm 1	**PM**	**B**
PM	$\frac{(1-w)^2}{(2+d)^2}, \frac{(1-w)^2}{(2+d)^2}$	$\frac{(1-w)^2\left(4-d^2-2d\right)^2}{16\left(2-d^2\right)^2}, \frac{(1-w)^2(2-d)^2}{8\left(2-d^2\right)}$
B	$\frac{(1-w)^2(2-d)^2}{8\left(2-d^2\right)}, \frac{(1-w)^2\left(4-d^2-2d\right)^2}{16\left(2-d^2\right)^2}$	$\frac{(1-w)^2\sqrt{1-d^2}\left(1-d+\sqrt{1-d^2}\right)^2}{4\left(1-d^2+\sqrt{1-d^2}\right)^2}, \frac{(1-w)^2\sqrt{1-d^2}\left(1-d+\sqrt{1-d^2}\right)^2}{4\left(1-d^2+\sqrt{1-d^2}\right)^2}$

TABLE 3 Parameter values: $w=0$ and $d=0.5$

	Firm 2	
Firm 1	**PM**	**B**
(A)		
PM	1, 1	1, 0.875
B	0.875, 1	0.866, 0.866
(B)		
PM	0.16, 0.16	0.1543, 0.1607
B	0.1607, 0.1543	0.1547, 0.1547

Note: (A) Optimal bargaining effort under B and PM. (B) Payoff matrix (profits) under B and PM: prisoner's dilemma: (B,B) is the unique pure-strategy Pareto inefficient Nash equilibrium, $\Delta_a > 0$, $\Delta_b < 0$ and $\Delta_c > 0$.

TABLE 4 Parameter values: $w=0$ and $d=0.8$

	Firm 2	
Firm 1	**PM**	**B**
(A)		
PM	1, 1	0.68, 1
B	0.68, 1	0.6, 0.6
(B)		
PM	0.127, 0.127	0.1046, 0.132
B	0.132, 0.1046	0.1041, 0.1041

Note: (A) Optimal bargaining effort under B and PM. (B) Payoff matrix (profits) under B and PM: Chicken game: (B,PM) and (PM,B) are two-pure strategy Pareto efficient Nash equilibria, $\Delta_a > 0$, $\Delta_b > 0$ and $\Delta_c > 0$.

codetermination, increase output and obtain a higher profit. No one is also interested in playing PM even when the rival plays B, because each player prefers to forgo being PM rather than be the only one to play PM, which leads to the worst possible outcome as a portion of its own profits is eroded by the union activity of the rival. Thus, regardless of the rival's activity no one will play PM, and everyone will forgo obtaining a higher profit by becoming an endogenously codetermined firm. However, if both players had decided to cooperate to become a codetermined firm, they would be better off. Thus, by making decisions that guarantee each player the best outcome unilaterally, both players are worse off than they would have been if they had both chosen to play B under endogenous codetermination: the pursuit of individual success can thus lead to collective failure. Can we then expect that both players, aware that they may get being disappointed by this result, will reach an agreement to jointly play PM? No, in fact if products are sufficiently differentiated there is no need for a law establishing codetermination as each firm has a unilateral incentive to become endogenously codetermined. Players' choices are consistent if and only if no one should regret their choice after knowing the rivals' strategy. In the endogenous codetermination game with sufficiently differentiated products, players make consistent decisions when they choose to play B. After both firms have chosen to play B, no one will regret the choice as anyone who had decided to play PM unilaterally would have been worse off. In contrast, players would have made conflicting decisions if they had both chosen to cooperate and play PM. In this case, each would have regretted their choice as playing B unilaterally would have been better off resulting in a higher payoff. On one hand, we must expect players to be able to achieve an agreement prescribing consistent choices (endogenous codetermination for both firms) because everyone is aware that no one after the agreement will be interested in the violation if the rival complies with it. In this sense, a codetermination law is not necessary in this case. On the other hand, we should not expect players to be able to achieve an agreement prescribing choices that are not mutually consistent (profit maximisation). This is because everyone is aware that no one will be interested in complying with that agreement if the rival complies with it. In this case, a codetermination law would be necessary, but under the assumption of a sufficiently differentiated product, the PM outcome in the market does not occur, and so the law would be unnecessary. Players could achieve a binding agreement requiring each of them to play PM if they were able to stipulate a binding contract, with penalties so severe that anyone who does not comply would have no incentive to violate it. The collective failure produced by the maximisation of the individual will by rational and selfish agents, therefore, can only be avoided if there is an institution capable of making the contracts binding. But this is a non-cooperative game, and, in this context, binding contracts cannot be implemented.

Differently, for larger values of d (Table 4, $d=0.8$), profits reduce in all cases, but there are no dominated strategies (chicken game) as the reduction in profits when both firms are codetermined is larger (32.7%) than that of the PM firm compared with the rival that is playing B (32.2%). In that case, employee representatives have almost near-parity rights as each firm in equilibrium maximises its profits when unions have 40% of the seats in the board. Interestingly, the anti-coordination game paradigm prevailing under endogenous codetermination is the counterpart for the prisoner's dilemma in the range of the described degree of the product differentiation parameter (Fanti et al., 2018; Kraft, 1998). Codetermination, therefore, becomes an anti-coordination game in which it is mutually beneficial for the players playing different strategies. This depends on the degree of product differentiation. As the loss of playing PM is smaller than that suffered if nobody plays PM, it will seem reasonable to play PM rather than engaging in a bargaining under codetermination by choosing to play B. Knowing this, if one believes one's opponent to be rational, one may well decide not to play PM at all. This is because the belief of each player may be such that both are rational thus leaving the other choosing to play PM to get the largest payoff. This holds when products are poorly differentiated as in this case production is larger (and profits are smaller) than when the products are largely differentiated and the degree of competition is higher: each firm aims to do not engage in a bargaining under codetermination to prevent profit reductions and get the largest payoff, but no one wants to leave it to the rival. Definitively, when products are poorly differentiated (or perfect substitutes), firms' profits tend to be lower than when products are largely differentiated and this, in turn, implies that the market share (in the markets for the relevant products) of each firm tends to reduce. This makes firms willing to do not accept bargaining employment with the union or to bargain by increasing the bargaining power as firms suffer from a fiercer competition in the product market in that case. In this case, each rational and selfish firm does not have a dominant strategy. Given the payoff matrix, no player is interested in playing PM if the rival plays PM as they all prefer to take the opportunity to get the highest possible payoff by playing B. Moreover, when products are poorly differentiated, everyone is interested in playing PM if the rival plays B to avoid the worst possible outcome, that is, profits of both firms are eroded because of the increased bargaining power of the unions (compared with when products were largely differentiated). Thus, no one is willing to cooperate with the rival to play PM, and no one wants to be left without codetermination, but both players unilaterally are willing to become bargainers under endogenous codetermination if the rival is profit maximiser. When the endogenous codetermination game falls under the chicken game paradigm (anti-coordination game), there are two pure-strategy Pareto-efficient Nash equilibria: if a player chooses to play B and the rival PM, no one will regret his/her decision because he/she would have been worse off in each different scenario. However, it is not easy to predict what the players will decide to do in this situation. In fact, each player would like to make decisions he/she will not have to regret and can expect that the other player will also be interested in making decisions he/she will not have to regret. No player, however, can predict what the rival will do, because everyone will be willing to play PM if he/she thinks the other will play B, but no one will be willing to play PM if he/she thinks the rival will play PM to take advantage of the greater profit opportunities given by strategy B in that case. So, if no one can predict what the other player will choose to do, no one can determine which decision guarantees the most satisfactory outcome. In these circumstances, it is possible that the players cannot make consistent actions. Consider, in fact, how players can make their decisions when they are uncertain about their rival's behaviour in this game. If they are cautious (risk averse), they will both choose to play PM to avoid the risk of being the only one to play PM thus obtaining the worst outcome if their rival plays B. If they are risk-takers, they will both choose to play B to have the opportunity to take advantage of the highest possible profit if the rival plays PM. Players may therefore find themselves in the unpleasant situation of playing either PM or B jointly, but in either case, after finding out what the rival has decided to do, each player will regret his choice. Finally, if the degree of risk aversion of the players differs, and the player with a higher degree of risk aversion chooses to play PM to avoid seeing his profits eroded by the bargaining activity of the trade union and the player with a lower degree of risk aversion choose instead to play B to get the opportunity to increase his profits, then the choices will be consistent, that is, no one will regret the choice made after knowing the strategy played by the rival, and no one could therefore have been better off. In this sense, mandatory codetermination would be Pareto inefficient as it would certainly worsen the situation of at least one player.

It would be interesting to pinpoint what happens in the case of homogeneous products ($d = 1$), resembling the paradox of voluntary (endogenous) codetermination. Under exogenous codetermination the unique pure-strategy Nash equilibrium of the game is (B,B), which results to be Pareto inefficient (Fanti et al., 2018; Kraft, 1998). Differently, in the case of perfect substitutability under endogenous codetermination, strategic interaction between two selfish players leads to the existence of a different paradigm: the anti-coordination game. Therefore, the paradox is avoided as a sufficient reduction in the degree of product differentiation gives firms a unilateral incentive not to accept aggressive bargaining with trade unions in order to avoid seeing their profits eroded, and so they are willing to accept to be both bargainers under codetermination (as profit maximisers!) up to a given threshold of product differentiation, above which the individual incentives change as the reduction in profits under B is larger than the reduction in profits under PM when $d > 0.76913$ so that no dominant strategy does exist and one firm will certainly play PM with the rival being bargainer under endogenous codetermination with a larger bargaining power than under the prisoner's dilemma.

Interestingly, though since Kraft (1998) the received literature dealing with exogenous codetermination has shown that when the union bargaining power is sufficiently high (i.e., the firm bargaining power is smaller than 25%) there exist two pure-strategy Nash equilibria given by (B,B) and (PM,PM), but PM payoff dominates B, so that firms have an incentive to coordinate to play PM (Fanti et al., 2018), *at least one firm always chooses to be a bargainer under codetermination* when the union bargaining power is endogenously chosen by the firms as a profit-maximising device. This is because the bargaining effort represents a strategic tool that firms may use for their own purposes. This result sharply changes qualitatively the main findings of the exogenous codetermination IO game-theoretic literature.

Finally, it could be instructive to go one step further and compare social welfare (W) at the equilibrium in the different scenarios that can indeed emerge in the choice of being codetermined or profit maximiser under endogenous codetermination. In doing this, we pinpoint that, when necessary (i.e., under B/B or B/PM), we will include the trade union's utility ($Z=Z_1+Z_2$ if both firms are codetermined or $Z=Z_i$, $i=\{1,2\}$ if only firm i is codetermined) in the social welfare function, which corresponds to the total wage bill—as union's members are also consumers—in addition to the consumer' surplus ($CS=\frac{1}{2}(q_1^2+q_2^2+2dq_1q_2)$) and the producers' surplus ($PS=\Pi_1+\Pi_2$). This agrees with Brander and Spencer (1988) and differs from Kraft (1998), who instead chose to do not include the trade union's utility within the social welfare function. Therefore, the social welfare functions in the symmetric subgames PM/PM and B/B are $W^{PM/PM}=CS^{PM/PM}+PS^{PM/PM}$ and $W^{B/B}=CS^{B/B}+PS^{B/B}+Z^{B/B}$, respectively, and the social welfare function in the asymmetric subgame B/PM is $W^{B/PM}=CS^{B/PM}+PS^{B/PM}+Z^{B/PM}$. We do not report here the social welfare functions in each case, but it is easy to show that $W^{B/B}>W^{B/PM}>W^{PM/PM}$ for any d and w. This means that mandatory codetermination is always Pareto worsening regardless of the type of paradigm emerging in the game as at least one of the two firms is always harmed by its possible enforcement (see Points (1) and (2) of Proposition 1). This is because if the game is a prisoner's dilemma, then both firms would be better off playing PM jointly (but they have an incentive to play B unilaterally). Differently, in the case of an anti-coordination game, its mandatory enforcement would let the firm that wanted to play PM in equilibrium be worse off.

3 | CONVEX (QUADRATIC) COSTS

The analysis discussed so far has followed an established industrial organisation literature with trade unions (e.g., Correa-López & Naylor, 2004) assuming a technology with constant return to scale, that is firms face constant average and marginal costs. This section modifies this hypothesis by introducing decreasing returns to scale (implying decreasing returns to labour and convex increasing marginal costs). For doing this, we assume that the production function of firm i is given by $q_i=\sqrt{L_i}$, so that $L_i=q_i^2$ represents the number of workers employed by firm i to produce q_i units of output of variety i. This technology allows for analytical tractability and implies that firms have quadratic costs, which is a typical example of increasing marginal costs. Though this assumption is just as standard as that of constant returns to labour, the effects it produces in a duopolistic codetermination context have not been previously investigated. Therefore, this section proceeds in this direction by also stressing the main differences compared with the case of constant returns to labour studied in Section 2. Indeed, the development of models with increasing marginal costs in the IO literature has focused mainly on profitability of a merger (Heywood & McGinty, 2007; Perry & Porter, 1985), market outcomes in a mixed duopoly (White, 1996), trade union behaviour different from codetermination—that is, centralised unionisation (Fanti & Meccheri, 2016), managerial delegation (Fanti & Meccheri, 2017) and corporate social responsibility (Fanti & Buccella, 2020).[3]

Under the assumption of increasing marginal costs, firm i's cost and profit functions are now respectively given by the expressions $C_i=wq_i^2$ and $\Pi_i=(p_i-wq_i)\,q_i$, where $w>0$. Firm i maximises Π_i by choosing product of variety i (q_i). Therefore, profits of firm i can be written as follows: $\Pi_i=(1-q_i-dq_j-wq_i)q_i$. Union i maximises the utility function $Z_i=w\,L_i$ by choosing employment L_i. The assumption of quadratic costs implies that $Z_i=wq_i^2$. The Nash bargaining function takes the form $\mathrm{N}_i=\left[(1-q_i-dq_j-wq_i)q_i\right]^{\beta_i}\left(wq_i^2\right)^{1-\beta_i}$, which should be maximised with respect to q_i.

3.1 | The symmetric subgame of endogenous codetermination (B/B)

If both firms are codetermined ($\beta_i<1$, $i=\{1,2\}$, $i\neq j$), the output produced by firm i come from the maximisation of the Nash bargaining function N_i with respect to q_i at the third stage of the game. Therefore,

$$\frac{\partial \mathrm{N}_i}{\partial q_i}=0\Leftrightarrow q_i(q_j)=\frac{(2-\beta_i)(1-dq_j)}{2(1+w)}, \tag{19}$$

allows us to obtain the reaction function of player i. By using the expression in Equation 19 for firm i and firm j, he equilibrium outcome produced by firm i as a function of the bargaining efforts of firm i and firm j is given by the following expression:

$$\bar{q}_i^{B/B}(\beta_i,\beta_j)=\frac{2(2-\beta_i)\left[1+w-d(1-\beta_j)\right]}{4(1+w)^2+2d^2(\beta_i+\beta_j)-d^2(4+\beta_i\beta_j)}. \tag{20}$$

Therefore, equilibrium profits of firm i as a function of the bargaining efforts of both firms are given by

$$\bar{\Pi}_i^{B/B}(\beta_i,\beta_j)=\frac{4\beta_i(2-\beta_i)(1+w)\left[1+w-d(1-\beta_j)\right]^2}{\left[4(1+w)^2+2d^2(\beta_i+\beta_j)-d^2(4+\beta_i\beta_j)\right]^2}. \tag{21}$$

At Stage 2, firm i and union i bargain if and only if the owner can choose the bargaining effort by maximising profits. Therefore, one gets

$$\frac{\partial \bar{\Pi}_i^{B/B}}{\partial \beta_i}=0\Leftrightarrow \beta_i(\beta_j)=\frac{2\left[(1+w)^2-d^2(1-\beta_j)\right]}{2(1+w)^2-d^2(1-\beta_j)}. \tag{22}$$

From the system of reaction-bargaining-functions of firm i and firm j, one can get the following symmetric equilibrium bargaining effort:

$$\beta_i^{B/B} = \frac{2}{d^2}\left[d^2 - (1+w)^2 + (1+w)\sqrt{(1+d+w)(1-d+w)}\right] < 1. \quad (23)$$

The main difference with respect to the case of constant returns to labour is that the optimal bargaining effort depends on the wage bargained at the economy-wide level and $\beta_i^{B/B} \neq 0$ when products are homogeneous ($d=1$). Indeed, a direct comparison between Equation 5 and 23 reveals that the bargaining power of the firm (resp. union) under the assumption of constant-returns-to-scale (constant average and marginal costs) is smaller (resp. larger) than under the assumption of decreasing-returns-to-scale (increasing marginal costs). This is because in the former case employment is proportional to output, whereas in the latter, employment is more than proportional to output so that firms are willing to bargain more aggressively with unions in the latter scenario.

Therefore, by using the expression in Equation 23, profits of firm i are given by

$$\Pi_i^{B/B} = \frac{\left(1+w-\sqrt{1+d+w}\sqrt{1-d+w}\right)\left[(1+w)\sqrt{1+d+w}\sqrt{1-d+w}+d^2-(1+w)^2\right]}{d^2\left[1+d+w-\sqrt{1+d+w}\sqrt{1-d+w}\right]^2}. \quad (24)$$

3.2 | The symmetric subgame of endogenous codetermination (PM/PM)

If both firms are profit maximisers ($\beta_i=\beta_j=1$, $i=\{1,2\}$, and $i \neq j$), the output that firm i should produce is chosen by the owner of the firm. Therefore, the maximisation of N_i with respect to q_i at the market stage of the game gives the reaction function of firm i:

$$\frac{\partial \mathrm{N}_i}{\partial q_i} = 0 \Leftrightarrow q_i(q_j) = \frac{1-dq_j}{2(1+w)}, \quad (25)$$

By using the expression in Equation 25 together with the corresponding counterpart for firm j, we get the symmetric equilibrium outcome produced by firm i:

$$q_i^{PM/PM} = \frac{1}{2(1+w)+d}. \quad (26)$$

Therefore, equilibrium profits of firm i are given by

$$\Pi_i^{PM/PM} = \frac{1+w}{[2(1+w)+d]^2}. \quad (27)$$

3.3 | The asymmetric subgame of endogenous codetermination (B/PM)

In the case of asymmetric behaviour—firm i is codetermined ($\beta_i < 1$) and firm j is profit maximiser ($\beta_j = 1$)—we have that firm i and its corresponding union bargain unit are involved in a bargaining aimed at maximising N_i with respect to q_i, whereas firm j maximises Π_j with respect to q_j. The reaction functions are given by

$$\frac{\partial \mathrm{N}_i}{\partial q_i} = 0 \Leftrightarrow q_i(q_j) = \frac{2-\beta_i-2dq_j(1-\beta_i)}{2(1+w)}, \quad (28)$$

and

$$\frac{\partial \mathrm{N}_j}{\partial q_j} = 0 \Leftrightarrow q_j(q_i) = \frac{1-dq_i}{2(1+w)}. \quad (29)$$

By using Equations 28 and 29, one gets the expressions of the quantities produced by the codetermined firm i and the profit maximising firm j as a function of the bargaining effort β_i along with the corresponding profit functions, that is,

$$\bar{q}_i^{B/PM} = \frac{(2-\beta_i)[2(1+w)-d]}{4(1+w)^2-d^2(2-\beta_i)}, \quad (30)$$

$$\bar{q}_j^{B/PM} = \frac{2(1+w)-d(2-\beta_i)}{4(1+w)^2-d^2(2-\beta_i)}, \quad (31)$$

$$\bar{\Pi}_i^{B/PM} = \frac{\beta_i(2-\beta_i)(1+w)[2(1+w)-d]^2}{\left[4(1+w)^2-d^2(2-\beta_i)\right]^2}, \quad (32)$$

and

$$\bar{\Pi}_j^{B/PM} = \frac{(1+w)[2(1+w)-d(2-\beta_i)]^2}{\left[4(1+w)^2-d^2(2-\beta_i)\right]^2}. \quad (33)$$

At Stage 2, firm i and union i bargain if and only if the owner can choose the bargaining effort to maximise its own profits. Therefore, the maximisation of the expression in Equation 32 with respect to β_i allows to get the following optimal bargaining effort in the case of asymmetric behaviour:

$$\frac{\partial \bar{\Pi}_i^{B/PM}}{\partial \beta_i} = 0 \Leftrightarrow \beta_i^{B/PM} = \frac{2\left[2-d^2+2w(2+w)\right]}{[2(1+w)+d][2(1+w)-d]} < 1. \quad (34)$$

By substituting out the expression in Equation 34 into Equations 32 and 33, one gets the equilibrium value of profits of the codetermined firm *i* and profit maximising firm *j*, which are respectively given by

$$\Pi_i^{B/PM} = \frac{[2(1+w)-d]^2}{8(1+w)\left[2-d^2+2w(2+w)\right]}, \quad (35)$$

and

$$\Pi_j^{B/PM} = \frac{\left[4(1+w)^2-2d(1+w)-d^2\right]^2}{16(1+w)\left[2-d^2+2w(2+w)\right]^2}. \quad (36)$$

3.4 | Nash equilibria and discussion under increasing marginal costs

The equilibrium outcomes of this game are summarised in Tables 5 (optimal bargaining effort) and 6 (profits) according to the strategies available to each firm. For analytical tractability (but without loss of generality) and to stress the main difference compared with the case of constant returns to labour, we simplify the analysis by considering the case of homogeneous products ($d=1$) as profits when both firms are codetermined are positive.

Proposition 2 clarifies the outcomes at the first stage of the endogenous codetermination game with decreasing returns to labour.

Proposition 2. (1) If $0 < w < 0.3$, then (B,PM) and (PM,B) are two pure-strategy Pareto-efficient Nash equilibria (anti-coordination game). (2) If $w > 0.3$, then (B,B) is the unique Pareto inefficient SPNE of the game (prisoner's dilemma).

Proof. Profit differentials Δ_a, Δ_b and Δ_c are the following:

$$\Delta_a = \Pi_i^{B/PM} - \Pi_i^{PM/PM} = \frac{1}{8(1+w)(3+2w)^2(1+2w^2+4w)} > 0,$$

$$\Delta_b = \Pi_i^{PM/B} - \Pi_i^{B/B} =$$
$$= \frac{1}{8(1+w)(1+2w^2+4w)^2\left(2+w-\sqrt{w}\sqrt{2+w}\right)^2} \times$$
$$\times\left[\sqrt{2+w}\left(-64w^{\frac{15}{2}}-448w^{\frac{13}{2}}-1264w^{\frac{11}{2}}-1840w^{\frac{9}{2}}-1468w^{\frac{7}{2}}-628w^{\frac{5}{2}}-129w^{\frac{3}{2}}-10w^{\frac{1}{2}}\right)+\right.$$
$$\left.+64w^8+512w^7+1680w^6+2912w^5+2860w^4+1584w^3+461w^2+59w+2\right],$$

and

$$\Delta_c = \Pi_i^{PM/PM} - \Pi_i^{B/B} =$$
$$= \frac{1}{(3+2w)^2\left(2+w-\sqrt{w}\sqrt{2+w}\right)^2} \times$$
$$\times\left[\sqrt{2+w}\left(-8w^{\frac{9}{2}}-40w^{\frac{7}{2}}-72w^{\frac{5}{2}}-54w^{\frac{3}{2}}-13w^{\frac{1}{2}}\right)+8w^5+48w^4+108w^3+110w^2+46w+4\right] > 0.$$

The sign of Δ_b changes depending on the relative size of *w*. Then, we have that (1) if $0 < w < 0.3$, then $\Delta_a > 0$, $\Delta_b > 0$ and $\Delta_c > 0$ and (2) if $w > 0.3$, then $\Delta_a > 0$, $\Delta_b < 0$ and $\Delta_c > 0$. **Q.E.D.**

In the case of decreasing returns to labour (increasing marginal costs), the outcome of the game depends on the size of the wage rate.

TABLE 5 Optimal bargaining effort under B and PM in the case of decreasing returns to labour ($d=1$)

	Firm 2	
Firm 1	**PM**	**B**
PM	1,1	$1, \frac{2(1+2w^2+4w)}{(3+2w)(1+2w)}$
B	$\frac{2(1+2w^2+4w)}{(3+2w)(1+2w)}, 1$	$-2w(2+w)+2(1+w)\sqrt{w(2+w)}$, $-2w(2+w)+2(1+w)\sqrt{w(2+w)}$

TABLE 6 Payoff matrix (profits) under B and PM in the case of decreasing returns to labour ($d=1$)

	Firm 2	
Firm 1	**PM**	**B**
PM	$\frac{1+w}{(3+2w)^2}, \frac{1+w}{(3+2w)^2}$	$\frac{(1+4w^2+6w)^2}{16(1+w)(1+2w^2+4w)^2}, \frac{(1+2w)^2}{8(1+w)(1+2w^2+4w)}$
B	$\frac{(1+2w)^2}{8(1+w)(1+2w^2+4w)}, \frac{(1+4w^2+6w)^2}{16(1+w)(1+2w^2+4w)^2}$	$\frac{(1+w-\sqrt{w}\sqrt{2+w})(-2w-w^2+\sqrt{w}\sqrt{2+w}+\sqrt[3]{w}\sqrt{2+w})}{(2+w-\sqrt{w}\sqrt{2+w})^2}, \frac{(1+w-\sqrt{w}\sqrt{2+w})(-2w-w^2+\sqrt{w}\sqrt{2+w}+\sqrt[3]{w}\sqrt{2+w})}{(2+w-\sqrt{w}\sqrt{2+w})^2}$

TABLE 7 Parameter values: $w=0.1$ and $d=1$

	Firm 2	
Firm 1	**PM**	**B**
(A)		
PM	1, 1	1, 0.73
B	0.73, 1	0.58, 0.58
(B)		
PM	0.107, 0.107	0.075, 0.11
B	0.11, 0.075	0.07, 0.07

Note: (A) Optimal bargaining effort under B and PM. (B) Payoff matrix (profits) under B and PM: Chicken game: (B,PM) and (PM,B) are two-pure strategy Pareto efficient Nash equilibria, $\Delta_a > 0$, $\Delta_b > 0$ and $\Delta_c > 0$.

TABLE 8 Parameter values: $w=0.32$ and $d=1$

	Firm 2	
Firm 1	**PM**	**B**
(A)		
PM	1, 1	1, 0.83
B	0.83, 1	0.78, 0.78
(B)		
PM	0.09, 0.09	0.085, 0.1
B	0.1, 0.085	0.0851, 0.0851

Note: (A) Optimal bargaining effort under B and PM. (B) Payoff matrix (profits) under B and PM: prisoner's dilemma: (B,B) is the unique pure-strategy Pareto inefficient Nash equilibrium, $\Delta_a > 0$, $\Delta_b < 0$ and $\Delta_c > 0$.

Differently, whether the codetermined duopoly falls within a prisoner's dilemma or an anti-coordination game depends on the relative size of the wage, which is bargained at the centralised or economy-wide level, and it is taken as given by each single firm in an industry. Therefore, there are similarities and differences compared to the endogenous codetermination game studied in Section 2 under the assumption of constant average and marginal costs. When centralised unions can bargain only a small wage, codetermination at the firm level is an anti-coordination game in which it is mutually beneficial for the players playing different strategies. This is because there are no dominant strategies and, if players are rational, nobody wants to leave the other choosing to play B thus getting the lowest payoff by playing PM (Table 7). The low level of wages bargained at the centralised level encourages decentralised unions to be bargain aggressively in bargaining with firms for employment so that the latter are not willing to accept to be both codetermined to avoid fierce competition with their own unions that in turn erodes profits.

When the wage bargained by centralised unions is larger, each firm has a dominant strategy (B), but both firms jointly prefer to be PM to get a larger payoff (Table 8). This is because the increase in the wage tends to reduce the quantity produced and increase the market price for all strategies. However, the percentage increase in the price when both firms are playing B is larger than the corresponding percentage reduction in production so that profits increase in that case. The high level of centrally bargained wages leads decentralised unions to bargain less aggressively with firms than when the centrally bargained wage was smaller. This implies that each firm is willing to accept the advantages of codetermination as the competition with its own decentralised union about employment is less aggressive in this case.[4]

We note that the same welfare outcomes obtained for the case of linear costs apply in the case of quadratic costs. Therefore, we do not speculate further in this direction.

4 | DISCUSSION AND CONCLUDING REMARKS

This article represents a modelling contribution going along the strain of theoretical research on codetermination, as was opened by McCain (1980) and later followed by Kraft (1998) and subsequent related game-theoretic works. Motivated by the evidence about the increasing importance of the institution of codetermination in Western countries, this research offers an alternative point of view about codetermination by using a game theoretic approach framed in a strategic competitive market (duopoly). Specifically, the work extends this strand of research by letting firms be able to choose endogenously the size of the bargaining effort by considering a tractable non-cooperative *endogenous codetermination game*. Unlike the previous literature on this issue, the present work assumes that the owner knows the union's bargaining effort and then chooses to bargain under codetermination if and only he can maximise profits and aims at speculating on the following issue: irrespective of the Nash equilibria emerging in the game, *the union's bargaining power evaluated in terms of the number of seats on the board of representative of the firm represents a strategic variable acting like the designing of a managerial delegation contract to incentivise the manager based on sales (quantities)*. The owner therefore can gradually use the union's bargaining power (strength) for his own purposes, which represents a new strategic device in the IO literature framed in strategic competitive markets. However, unlike the managerial delegation literature, the equilibrium paradigm emerging in the endogenous codetermination game may differ from the prisoner's dilemma.

Codetermination is an institution that plays an important role in the protection of workers' rights and the improvement of working conditions. Among other North European countries, it has become relevant in the German industry since the issue of The German Codetermination Act (1976) by also affecting the designing of German industrial policy. In contrast to Kraft (1998), who built on an exogenous codetermination set up showing that codetermination might emerge as a Pareto inefficient market outcome (prisoner's dilemma) in a standard Cournot duopoly with homogeneous products (extended by Fanti et al., 2018 with product differentiation), this article provided an alternative point of view about the institution of codetermination. When codetermination is endogenous, mandatory codetermination is always Pareto worsening.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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INFORMED CONSENT

Informed consent was obtained from all individual participants included in the study.

ENDNOTES

[1] Of course, given the main features of codetermination, which greatly differ from those relevant for institutions such as the efficient bargaining, the right-to-manage and the monopoly union, the wage is the object of a centralised or economy-wide agreement so that both parties consider it as given at the firm or decentralised level.

[2] We will see later, however, that (B,B) will be a Nash equilibrium of the game when products are sufficiently differentiated and eventually perfect substitutes.

[3] The last reference can be useful for an example of industries displaying decreasing returns to scale and increasing marginal costs.

[4] This follows by evaluating the sign of the second order derivative of the expression in 20 with respect to β_i and w, which is always negative.

DATA AVAILABILITY STATEMENT

Data sharing not applicable to this article as no data sets were generated or analysed during the current study.

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