Codetermination, price competition and the network industry

Luciano Fanti • Luca Gori

Abstract This research develops a tractable two-stage non-cooperative game with complete information describing the behaviour of price-setting firms that must choose to be profit maximisers or bargainers under codetermination in a network industry with horizontal product differentiation. The existing theoretical literature has already shown that codetermination might arise as the endogenous market outcome in a strategic competitive quantity-setting duopoly. In sharp contrast with this result, the present article shows that codetermination does never emerge as a Nash equilibrium in a price-setting non-network duopoly. Then, it aims at highlighting the role of network externalities in determining changes of paradigm of the game and letting codetermination become a sub-game perfect Nash equilibrium when prices are strategic substitutes or strategic complements. This equilibrium may be Pareto efficient. Results allow distinguishing between mandatory codetermination and voluntary codetermination. The article also proposes a model of endogenous codetermination according to which every firm may choose to bargain with its own corresponding union bargaining unit only whether the firm's bargaining strength is exactly the profit-maximising one. The equilibrium outcomes emerging in this case range from a uniform Nash equilibrium, in which both firms are codetermined, to mixed Nash equilibria, in which only one of them chooses to be codetermined. These results are "network depending" and do not hold in a non-network duopoly.

Keywords Codetermination; Network externalities; Price competition

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1. Introduction

The aim of this article is to link two distinct but related issues of the recent theoretical literature belonging to the Industrial Organisation, that is codetermination and network externalities. By following the contributions led by Kraft (1998) about the market effects of *bargaining on employment without any wage negotiations*, this work takes codetermination seriously and aims at analysing whether firms' owners have an incentive of being (voluntarily) profit maximisers or bargainers (together with their own union bargaining unit) under codetermination in a *network industry* with horizontal product differentiation. The existence of products for which the utility drawn by each consumer increases with the number of users is a typical characteristic of network externalities in consumption. Then, a consumer's demand also depends on the demand of other consumers. The simple mechanism of network effects we are accounting for in this work follows the tradition initiated by Katz and Shapiro (1985), where the externality tends to increase or reduce the market size depending on whether it is positive or negative. Specifically, the article considers a non-cooperative price-setting strategic competitive duopoly with complete information and positive externalities, where rational players (firms) play a two-stage game solved according to the backward induction logic. At stage 1 (*the codetermination stage*), each owner must choose to be either a codetermined or profit-maximising firm. At stage 2 (*the bargaining market stage*), firms either choose the price in the output market in the case of profit maximisation or bargain it together with unions in the case of codetermination. From theoretical and modelling perspectives, the article wants to gather elements belonging to two distinct burgeoning strands of research of the Industrial Organisation literature. This is because codetermination and network externalities characterise several existing industries in developed countries (e.g., mobile telecommunications and related services in Germany). The research question of the work is the following: may codetermination emerge as the endogenous market outcome of firms competing in a Bertrand rivalry setting rather than coming from legislative rules? The main finding on price-setting with and without network effects leads to a reversal result. In the absence of network goods (standard output market), firms always choose to be profit maximisers, so that codetermination can emerge only from ad hoc legislation. Differently, in network industries each firm can *voluntarily* choose to be codetermined. This outcome holds when prices are strategic complements (products are substitutes) or strategic substitutes (products are complements) and can be Pareto inefficient (prisoner's dilemma) or efficient (deadlock) depending on both the relative degree of product differentiation and the relative bargaining power of the unions.[1] In a market for non-network goods, an increase in the bargaining power of the unions is never enough to let each firm having a unilateral incentive to play codetermination (irrespective of the degree of product differentiation). This is because when employment and production increase, the market price goes down and this negative effect on profits always dominates the positive one emerging from the increased employment and production levels. In a market for network goods, there exists a reversal result. An increase in the strength of the (positive) network externality generates an increase in both the market size and the quantity customers are willing to consume for any given value of the price. This strengthens the beneficial effect of codetermination by generating an increase in employment, output and profits thus giving each firm the incentive to become codetermined without the need of any ad hoc legislation. This is essentially because employment in a network market is already high and unions may behave less aggressively (as a bargaining unit) than they would behave in a corresponding non-network setting. When the degree of product differentiation is low, products are perceived as homogeneous and the degree of competition between firms is large. In this case, there exists a prisoner's dilemma, i.e. players (firms) have an incentive to coordinate to play profit maximisation, but no one has a unilateral incentive to deviate from codetermination. When the degree of product differentiation becomes larger, products are perceived as highly heterogeneous and the degree of competition between firms becomes lower. Then, codetermination becomes the dominant strategy and firms

[1] A deadlock game (or anti-prisoner's dilemma) implies that there is no conflict between self-interest and social interest, and the strategy that is the mutually most beneficial is the dominant strategy. Differently, in a prisoner's dilemma there is a conflict between self-interest and social interest and the strategy that is the mutually most beneficial is a dominated strategy.

have a unilateral incentive to coordinate to play codetermination (deadlock). In other words, in a network industry the increase in both employment and profits are stimulated not only by price changes (due to codetermination) but also by the increase in the market size generated by the network.

Some clarifications about the working of codetermination and network externalities are now in order.

Codetermination. Codetermination is an institution implying, broadly speaking, that employees' representatives sit on the supervisory board in large companies and take several decisions at both the establishment and workplace levels, especially those regarding employment. It represents a relevant feature of the German industry where regulatory interventions in the labour market affected efficiency and the bargaining power on the workers' side, but comprehensive legislation on board-level representation is widespread also in other North European countries (e.g., Austria, Denmark, Norway and so on), as was pointed out in Schulten and Zagelmeyer (1998).[2] However, the German system remains the most interesting and complex example of employment codetermination. Although both the rules to setting works councils and specific laws about establishment and workplace codetermination have changed several times since their introduction,[3] by favouring or discouraging – as swings of a legislative pendulum – the formation and competence of work councils, the German system has often been regarded as pioneering. Indeed, it has become

[2] Amongst the 16 countries covered by European Industrial Relations Observatory (EIRO) only the UK has no statutory form of board-level representation or significant collectively agreed provisions. Differently, Belgium and Italy have no general legislation or widely applicable collective agreement provision for board-level representation but there are specific regulations for board-level employee representatives in some public companies (e.g., the state railway in Belgium and several public companies in Italy).

[3] In 1848, the Frankfurt Parliament started thinking about the development of specific workers' councils for industry organisations to bound corporate power in large companies. In 1920, the *Betriebsrätegesetz* (Works Council Act) established that firms with more than 20 employees should compulsory introduce consultative bodies to represent the economic interest of workers. In 1951, the *Montan-Mitbestimmungsgesetz* (Coal, Steel and Mining Codetermination Law) introduced codetermination in firms with more than 1,000 employees to protect workers' rights through the (near-parity) participation of workers' representatives at the supervisory boards. In 1976, the German Codetermination Act (*Mitbestimmungsgesetz*) introduced the possibility of equal representation of employers and employees' representatives on the supervisory board in large companies with more than 2000 employees (see McGaughey, 2015 for a study about the history of German labour laws).

increasingly important especially in recent decades due to the worldwide diffusion of the decline in private-sector union density, representing an exemplary system able to provide a potential solution to the problem of sub-optimal workers involvement hinted at by the facts of union decline. The European Union[4] has referred to the German institution in its enduring political debate on the designing of various systems seeking to increase workers participation (see the Davignon report published on October 27th, 1970 by the European Commission and more recently by the legislation establishing a general framework for determining minimum information and consultation rights for workers at the workplace, Official Journal, March 2002).

Also, much (sometimes rather critical) attention was paid to codetermination in the German political debate. For instance, it has been argued that codetermination at the establishment level was under-provided by the market despite the mandatory (but not automatic) legislation, and that changes regarding the structure and functioning of codetermination were required to improve its economic performance (*Kommission Mitbestimmung*, 1998).[5] Together with the latter argument, there were also demands from the union movements for reforming it, with the consequence of a new Works Constitution Act in July 2001 aiming at increasing the influence of the works council in Germany.

Network externalities. Another stylised fact of actual (modern) economies is represented by the existence of several products for which the utility drawn by each consumer increases with the number of users, i.e. the total sales increase individual welfare (e.g., Katz and Shapiro, 1985). These products are characterised by a positive consumption externality and are called network goods. Examples of network industries – that are often subject to the rules of codetermination in Germany and other North European countries – include the production of software, computers, consumer electronics, telephones and other communication services (e.g., Shy, 2001). More in general,

[4] Even the US considered works councils according to the German example (Dunlop Commission, 1994).
[5] The Bertelsmann and Hans Böckler Foundations set up the special Codetermination Commission/*Kommission Mitbestimmung* in 1996.

positive network externalities may exist for products that a consumer wants to consume because others do (the so-called Bandwagon Effect). Moreover, a consumer/user's demand for a network good may positively depend on the number of other consumers/users through other ways. This is the case when customers perceive a product as a signal of the availability of after-sale services for long-lasting consumers or product quality.[6] For instance, in the market of mobile telecommunications there are several possible sources of network effects (Baraldi, 2012). (1) When there is an increasing number of users belonging to a network, it becomes more attracting for others buying a mobile phone and subscribing to and being part of the same network. (2) The network expansion drives the usage volume of people already using mobile telecommunication. Then, the usage volume of existing subscribers is expected to increase with the total number of mobile telephone subscribers. (3) By considering the recent approach of the social interaction theory (e.g. Schoder, 2000), another source of network externality is the need of people to buy, consume and behave as their follows. This is the case of a network effect driven by a conformist behaviour.

Codetermination and network externalities. Codetermination and the production of network goods are two distinct but related issues, and there exists empirical evidence of remarkable network effects also for industries located in countries with the institution of codetermination (e.g., Germany). For example, by focusing again on the case of telecommunications, Doganoglu and Grzybowski (2007) estimated a system of demand functions for mobile subscribers in Germany from January 1998 to June 2003 (data on mobile subscriptions was collected from the Internet site run by the German regulator – RegTP) finding that network played a significant role in the diffusion of mobile services in the German telecommunications market.[7] More recently, Baraldi (2012) analysed 30 OECD countries by specifying and estimating a model of consumer demand for mobile telephone calls

[6] Networks may include several durable goods to the extent that the utility of consumers is positively related to the quality of post-sale services and a higher consumer-base is positively related to better post-sale services.
[7] "If there were no network effects, the industry growth would be stimulated only by price changes… the penetration level in the absence of network effects could be at least 50% lower, compared to the current case." (Doganoglu and Grzybowski, 2007, p. 77).

from 1989 to 2006 aimed at identifying the extent of network effects. The author showed that the network effect is large (though less than the one found by Doganoglu and Grzybowski, 2007) also for countries such as Austria and Germany. These results confirm that the competition analysis under codetermination in industries producing network goods should account for both the existence and intensity of network effects.

Consumers' expectations about the total sales of goods and services may in principle be affected by different labour market institutions. As in several network markets firms compete on prices (e.g., internet service providers, financial services, mobile phones and so on), they might also have an incentive to differentiate their products especially to avoid losing the customers' demand when prices are larger than those of the rivals.[8] Against this backdrop, this article aims at re-examining the theoretical literature on codetermination by considering the mode of product market competition alternative to Cournot rivalry, i.e. price competition, and accounting for network goods in a theoretical Bertrand's duopoly with differentiated products. In sharp contrast with the related literature so far focused only Cournot settings, codetermination can never emerge as a market outcome in standard non-network industries, whereas a reversal result exists in industries producing network goods. The main policy implication of these results is the following: codetermination in price-setting non-network industries can emerge only from ad hoc legislation (mandatory codetermination), though this policy represents a Pareto dominated outcome when prices are strategic complements, whereas being Pareto improving when prices are strategic substitutes and products are sufficiently complementary. In fact, a high degree of product complementarity implies that firms behave as if they jointly determined the strategic variable in the output market and codetermination strengthens this effect by reducing the market price. If the industry produces

[8] The theoretical literature has attempted identifying when and how firms should compete on prices rather on quantities (Kreps and Scheinkman, 1983). In a nutshell, quantity competition seems to prevail when production decisions were made in advance and they are committed to selling all the output because of, e.g., sunk production costs or costly inventories. Price competition prevails when the production capacity is flexible enough to allow firms satisfying the demand arising at the announced price. For instance, the airline industry is typically considered an illustrative example of competition resembling either Bertrand rivalry or Cournot rivalry depending on the business cycle.

network goods, the externality increases the market size allowing unions to behave less aggressively in the bargaining, so that firm's owners more easily agree to bargain with them in the output market. Therefore, depending on the degree of product differentiation and the relative bargaining power, codetermination can emerge as a market outcome and this equilibrium may be the mutually most beneficial one (deadlock) or a prisoner's dilemma (voluntary codetermination). The work therefore proposes some policy recipes in term of mandatory codetermination rules versus voluntary codetermination. It also speculates about the possibility of letting codetermination become endogenous by considering firms that choose to be codetermined only whether their own bargaining power is the profit-maximising one. The main findings are in line with the case of exogenous codetermination (Kraft, 1998; Fanti et al., 2018) even though multiple mixed Nash equilibria may emerge in that case.

The rest of the article proceeds as follows. Section 2 reviews the existing literature on codetermination and network externalities framed in oligopoly contexts. Section 3 sets up a network-codetermination game with price competition by also presenting and discussing the main results of the work. Section 4 extends the model to the case of endogenous codetermination by letting firms choosing the profit-maximising degree of bargaining. Section 5 outlines the conclusions. The Appendix deals with the case of heterogeneous codetermination.

2. Literature review on codetermination and network effects

Given the critical role of network effects in the emergence of codetermination as an endogenous outcome in price-setting strategic competitive markets, it would be convenient surveying the existing literature on codetermination and network externalities essentially framed in oligopolistic settings.

On theoretical grounds, McCain (1980) provided the first contribution about codetermination aiming at setting up a rigorous framework to develop a theory of the organisation of the firm and explain their behaviour when control is shared between workers and shareholders' representatives (near-parity representation). After almost two decades, Kraft (1998) considered a tractable Cournot model on the strategic effect of employment bargaining in duopolistic interaction with homogenous products showing that profit maximising firms have an incentive to become bargainers over employment (prisoner's dilemma). Specifically, he considered a game played by firms that must choose between profit maximisation and codetermination and showed that the latter can be the dominant strategy. However, this Nash equilibrium is Pareto inefficient in line with the common wisdom that the presence of unions committing firm on employment harms firm's profitability. Then, Kraft (2001) re-examined his previous work by accounting for a general oligopolistic market and confirmed the existence of a prisoner's dilemma for a large range of the union's bargaining power. Other contributions have extended the early literature. Three of them introduced R&D activities in a codetermined setting. Specifically, Granero (2006) showed that codetermination may allow increasing market share, employment and innovativity in a quantity-setting duopoly with managerial firms.[9] Then, by taking Kraft (1998, 2001) as a starting point, Kraft et al. (2011) studied the effects of the German Codetermination Act of 1976 on the innovative activity of German firms,[10] finding no support to conclude that codetermination negatively affects technological progress and innovativity. Finally, Fanti et al. (2018) revisited Kraft (1998) and Kraft et al. (2011) finding that their results may not be robust to a more general Cournot setting including horizontal product differentiation à la Singh and Vives (1984) and R&D. Differently, Gürtler and Höffler (2015) started from the (stylised) fact that workers protection in the European Union is stronger than in the US and stressed the role played by works councils in German codetermined large companies by focusing on the role of works councils on the monitoring of workers.

On the side of empirical evidence, there is little and controversial work. For instance, Frick (2001) – in a production function study using the 1998 wave of the IAB Establishment Panel –

[9] The objective function of the firm/manager was assumed a weighted sum of profits and the wage bill, where the relative proportions of board votes of shareholders and workers represent the (exogenous) weight of the problem.
[10] They considered an R&D duopoly (where R&D was not the subject of negotiations) and exogenously compared profits and the R&D innovative activity under codetermination and profit maximisation.

obtained a positive evidence on firms' performance. Specifically, he found that the existence of works council is associated with 25 (resp. 30) percent higher labour productivity in western (resp. eastern) Germany. However, according to Addison et al. (2004) that correlation may reflect omitted variables biases as well as an inadequate measure of capital (proxied by the log of replacement investment).[11] Similarly, by considering a stochastic production frontier approach and a large panel data set, Schank et al. (2004) investigated whether works councils act as sand or grease in the operation of German firms. Their analysis suggested that establishments with and without a works council did not exhibit significant differences in efficiency, that is they fail to detect material differences in establishment efficiency by works council status. By also reviewing the other literature documenting the effects of codetermination on establishment or firm performance (i.e., amongst others, FitzRoy and Kraft (1987) and Addison et al. (1993) with regard to the evidence on total factor productivity, FitzRoy and Kraft (1985), Addison et al. (1993) and Addison et al. (1997) on firm profitability, Addison et al. (1993) studied also the effects of codetermination on the investment in physical capital, FitzRoy and Kraft (1990), Schnabel and Wagner (1994), and Addison et al. (1997) analysed how codetermination affects investments in intangible capital, Gorton and Schmid (2004) with regard to the evidence on the market value of firms), we may argue that it is difficult to find contributions that support codetermination. This is because most of these studies pinpointed to it adversely affect performances or, at best, there exist statistically insignificant economic effects. Addison et al. (2004) also provided new information on the extent of works councils after the reform of 2001. They investigated the effects of works council formation on labour productivity, financial performance and employment development and showed that the absence of codetermination did not appear to have negative consequences for workplace productivity, profitability, and employment. Finally, Kraft (2018) considered an empirical test

[11] Other scholars have found a positive correlation between codetermination and firm performances. For instance, Cable and FitzRoy (1980) and FitzRoy and Kraft (2005) concluded for positive effects of codetermination on labour productivity.

covering German data from stock companies from 1973 to 1990 finding that codetermination does not affect labour productivity but increases the workers' bargaining power.

On the side of network effects, the theoretical literature on network externalities has recently seen a renewed interest with contributions that re-examined several models and changed some established results of the Industrial Organisation literature. For instance, 1) Hoernig (2012), Bhattacharjee and Pal (2014), and Chirco and Scrimitore (2013) showed that the established results of the oligopoly managerial delegation literature may not hold, 2) Fanti and Buccella (2017, 2018) found that the common wisdom regarding the bargaining agenda (between unions and firms) and corporate social responsibility may change, 3) Song and Wang (2017) showed that the strength of the network externality affects collusion between firms, which becomes more likely when products are close substitutes.

None of the existing works, however, has studied which is the outcome of network markets with strategic competitive codetermined firms. This is the aim of the next section.

3. The network-codetermination game with price competition

This section begins with by detailing the main features of a network-codetermination non-cooperative (two-stage) game with price competing firms and complete information. The production side of the economy is comprised of two firms (duopoly) each of which produces a commodity perceived by customers as horizontally differentiated compared to the commodity produced by the rival (Singh and Vives, 1984). The technology used by firm $i = \{1,2\}$ to produce goods of variety i employs a production function with constant returns to labour, so that $q_i = L_i$, where L_i is the labour force hired by the firm and q_i is the quantity sold in the output market. Each firm faces a constant marginal (and average) cost $0 \leq w < 1$ (Correa-López and Naylor, 2004) representing the wage per unit of labour set in a centralised or industry-wide bargaining, which is taken as given by each single firm (Kraft, 1998; Fanti et al., 2018). Therefore, firm i's profits are $\Pi_i = (p_i - w)q_i$, where $p_i \geq 0$ is firm i's price.

There exists a continuum of identical consumers with preferences represented by a separable utility function $V(q_1, q_2, y_1, y_2, m)$, which is linear in the numeraire good m (produced in a competitive sector). The representative consumer maximises $V(q_1, q_2, y_1, y_2, m) = U(q_1, q_2, y_1, y_2) + m$ subject to the budget constraint $p_1q_1 + p_2q_2 + m = R$, where $U(q_1, q_2, y_1, y_2)$ is a twice continuously differentiable function, q_1 and q_2 are the control variables of the problem and R is the consumer's exogenous nominal income. This income is high enough to avoid the existence of corner solutions. Different from the traditional industrial organisation literature, we assume the existence of network externalities in consumption. This implies that one person's demand also depends on the demand of other consumers. The simple mechanism of network effects we are accounting for in this work follows the tradition initiated by Katz and Shapiro (1985). The issue of network externalities has become relevant especially due to the tremendous growth of the internet-related activities (e.g., online games, telephone and so on) in markets where firms are price setters.

By following the spirit of several recent works dealing with network effects in a strategic competitive framework (Hoernig, 2012; Bhattacharjee and Pal, 2013; Chirco and Scrimitore, 2013; Pal, 2014, 2015; Song and Wang 2017), we assume that consumers' preferences are represented by the following utility function:

$$U(q_i, q_j, y_i, y_j) = q_i + q_j - \frac{1}{2}(q_i^2 + q_j^2 + 2dq_iq_j) + n[q_i(y_i + dy_j) + q_j(y_j + dy_i)] - \frac{n}{2}(y_i^2 + y_j^2 + 2dy_iy_j), \quad (1)$$

where $i, j = \{1,2\}$ $(i \neq j)$, y_i denotes consumers' expectations about firm i's equilibrium total sales and represents a consumption externality, $0 \leq n < 1$ is the strength of this (positive) externality ($n = 0$ represents the standard case of non-network markets), and $-1 \leq d \leq 1$ is a parameter capturing the degree of product differentiation as perceived by customers. When $d = 1$ (resp. $d = -1$) products are perfect substitutes (resp. perfect complements), whereas $0 < d < 1$ (resp. $-1 < d < 0$) reflects the case of imperfect substitutability (resp. imperfect complementarity). The case $d = 0$ implies that each firm behaves as if it were a monopolist for its own product. We note that the last addendum in (1) is a specific symmetric function of expectations such that for each given consumption vector (q_1, q_2) utility is highest if expectations are correct.

The utility function in (1) is a modified version of the one used by Singh and Vives (1984). The reason why adopting this version here is simple. The utility function popularised by Hoernig (2012) is not defined for the case of homogeneous goods. Although we do not include the case of perfect substitutability to avoid the model falls within the Bertrand paradox, we preferred employing the version expressed in (1) to overcome this lacuna. By solving the utility maximisation programme gives the following linear inverse demand of product of variety i:

$$p_i = 1 - q_i - dq_j + n(y_i + dy_j),\ i,j = \{1,2\},\ i \neq j. \tag{2}$$

From (2), it is easy to see that network externalities enter additively in the demand function. An increase in the strength of network effects ($n \uparrow$) causes an outward shift in the demand curve that in turn implies an increase in the quantity bought by consumers for any given value of the price. This externality therefore acts as a device that increases the market size. As in the present model firms compete on prices, we need employing the direct demand version of (2), i.e. q_i as a function of prices of products of both varieties, which is obtained by inverting the direct demand of firm i and using the corresponding counterpart version of firm j. This is given by the following expression:

$$q_i = \frac{1 - p_i - d(1 - p_j)}{1 - d^2} + ny_i,\ i,j = \{1,2\},\ i \neq j. \tag{3}$$

By following the literature led by Kraft (1998), we assume the existence of codetermination. Therefore, firms' representatives (owners) bargain with employees' representatives (unions) over employment but not over wages on the supervisory board. By translating this concept in a price-setting duopoly industry, we should have that the objective of firm i would be maximising its own profits Π_i with respect to p_i. By using the inverse demand Eq. (3), profits are the following:

$$\Pi_i = (p_i - w)\left[\frac{1-p_i-d(1-p_j)}{1-d^2} + ny_i\right]. \tag{4}$$

Differently, each firm-specific union aims at maximising its own utility $Z_i = (w_i - w°)L_i$ with respect to p_i by knowing that $L_i = q_i$ and using the quantity dictated by the direct demand in (3), where $w°$ is the reservation (or competitive) wage, which is set to zero without loss of generality, henceforth. Therefore, the utility function of the union bargain unit of firm i simplifies as follows:

$$Z_i = w\left[\frac{1-p_i-d(1-p_j)}{1-d^2} + ny_i\right]. \tag{5}$$

The Nash bargaining over prices between firm i and its own union bargain unit takes the form:

$$N_i = \Pi_i^{\beta} Z_i^{1-\beta} = \left\{(p_i - w)\left[\frac{1-p_i-d(1-p_j)}{1-d^2} + ny_i\right]\right\}^{\beta}\left\{w\left[\frac{1-p_i-d(1-p_j)}{1-d^2} + ny_i\right]\right\}^{1-\beta}, \tag{6}$$

where p_i is the control variable, y_i is the positive externality induced by the network and $0 < \beta \leq 1$ is the relative bargaining power of firm i. The network good in this case has the characteristics of a public good as the consumption by one consumer generates a positive external effect which is both non-excludable and non-rivalrous. By following Kraft (1998) and the theoretical literature on codetermination, the bargaining power of the union is homogenous and constant, and the threat points are set at zero. The assumption of an exogenous bargaining strength also follows an established literature on union bargaining (see, amongst others, Dowrick, 1989; Petrakis and Vlassis, 2000; Correa-López and Naylor, 2004; Granero, 2006). In this strategic context, it allows studying under which circumstances employment bargaining without any wage negotiations emerges voluntarily in the market (as codetermination is quite absent in countries without specific regulations) and then whether mandatory codetermination or voluntary contractual agreements between the firm and its union bargaining unit may be efficient or not. Section 4 extends the model to endogenous codetermination by letting firms choose to be bargainers only whether they maximise their own profits with respect to the bargaining power. The Appendix extends the model to the case of heterogeneous exogenous bargaining power. The approach used here represents a modelling representation of Furubotn (1988), who conjectured that voluntary codetermination may be efficient.

The timing of the events of this non-cooperative two-stage simultaneous game with complete information is the following. At the *codetermination stage* (stage 1), each owner must choose to be either a codetermined or profit-maximising firm. At the *bargaining market stage* (stage 2), firms either choose the price in the output market in the case of profit maximisation or bargain it together with unions in the case of codetermination in a network industry. As is usual from Katz and Shapiro (1985) and Hoernig (2012), consumers have rational expectations. Therefore, at the second stage of the game we impose that $q_1 = y_1$ and $q_2 = y_2$ hold in equilibrium. We proceed into the analysis according to the standard backward induction logic.

Codetermination. First, we consider that both firms are codetermined ($\beta < 1$) so that the price should be set for product of variety i at the second stage of the game is chosen by firms and employees' representatives by maximising the expression in (6) with respect to p_i. Therefore, the reaction function of the ith firm is given by:

$$\frac{\partial N_i}{\partial p_i} = 0 \Leftrightarrow p_i(p_j, y_i, y_j) = \frac{w+\beta[1-d+dp_j+(1-d^2)ny_i]}{1+\beta}, \tag{7}$$

From (7), an increase in the strength of the network externality shifts upward the reaction function and then causes an increase in the price consumers are willing to pay for any given value of the quantity produced. When products are substitutes ($0 < d < 1$), the reaction functions of both firms (whose behaviour is symmetric in this case) are upward sloping and prices are strategic complements. When products are complements ($-1 < d < 0$), the reaction functions of both firms are downward sloping and prices are strategic substitutes. By using (7) together with the corresponding counterpart of firm j and knowing that $y_i = q_i$ and $y_j = q_j$, $i, j = \{1,2\}$ $(i \neq j)$, we definitely get the equilibrium outcome of firm i, that is:

$$p_i^{B/B} = \frac{\beta(1-d)+w(1-n)}{1-n+\beta(1-d)}, \tag{8}$$

where the superscript B denotes "bargaining" under codetermination. Therefore, equilibrium quantity and profit of firm i are respectively given by:

$$q_i^{B/B} = \frac{1-w}{(1+d)[1-n+\beta(1-d)]}, \tag{9}$$

and

$$\Pi_i^{B/B} = \frac{\beta(1-w)^2(1-d)}{(1+d)[1-n+\beta(1-d)]^2}. \tag{10}$$

Straightforward algebra from (8), (9) and (10) shows that an increase in n causes a monotonic increase in the price consumers are willing to pay for any given value of the quantity of products of variety i and variety j, as well as in the quantity produced by both firms and their own profits.

Profit maximisation. If both firms are profit maximisers ($\beta = 1$), the equilibrium value of price, output and profit of firm i are the following:

$$p_i^{PM/PM} = \frac{1-d+w(1-n)}{2-n-d}, \tag{11}$$

$$q_i^{PM/PM} = \frac{1-w}{(1+d)(2-n-d)}, \tag{12}$$

and

$$\Pi_i^{PM/PM} = \frac{(1-w)^2(1-d)}{(1+d)(2-n-d)^2}, \tag{13}$$

where the superscript PM denotes "profit maximisation".

Asymmetric behaviour. Let us consider now the asymmetric case in which firm 1 is codetermined and firm 2 is a profit maximiser. At the bargaining market stage, firm 1 and its corresponding union bargaining unit are involved in a bargaining aimed at maximising N_1 with respect to p_1, whereas firm 2 maximises Π_2 with respect to p_2. The reaction functions are given by:

$$\frac{\partial N_1}{\partial p_1}=0 \Leftrightarrow p_1(p_2,y_1,y_2)=\frac{w+\beta[1-d+dp_2+(1-d^2)ny_1]}{1+\beta}, \tag{14}$$

and

$$\frac{\partial \Pi_2}{\partial p_2}=0 \Leftrightarrow p_2(p_1,y_1,y_2)=\frac{w+1-d+dp_1+(1-d^2)ny_2}{2}. \tag{15}$$

By imposing the conditions $y_1=q_1$ and $y_2=q_2$, we easily get the equilibrium values of prices set by firm 1 and firm 2, respectively:

$$p_1^{B/PM}=\frac{w(1-n)(2-n+\beta d)+\beta[2-n-d(1-n+d)]}{(1-n)(2-n)+\beta(2-n-d^2)}, \tag{16}$$

and

$$p_2^{B/PM}=\frac{w(1-n)(1-n+d+\beta)+(1-n)(1-d)+\beta(1-d^2)}{(1-n)(2-n)+\beta(2-n-d^2)}. \tag{17}$$

Therefore, the equilibrium values of the quantities produced by firm 1 and firm 2 and their own corresponding profits are the following:

$$q_1^{B/PM}=\frac{(1-w)(2-n+d)}{(1+d)[(1-n)(2-n)+\beta(2-n-d^2)]}, \tag{18}$$

$$q_2^{B/PM}=\frac{(1-w)[1-n+\beta(1+d)]}{(1+d)[(1-n)(2-n)+\beta(2-n-d^2)]}, \tag{19}$$

and

$$\Pi_1^{B/PM}=\frac{\beta(1-w)^2(1-d)(2-n+d)^2}{(1+d)[(1-n)(2-n)+\beta(2-n-d^2)]^2}, \tag{20}$$

$$\Pi_2^{B/PM}=\frac{(1-w)^2(1-d)[1-n+\beta(1+d)]^2}{(1+d)[(1-n)(2-n)+\beta(2-n-d^2)]^2}. \tag{21}$$

Equilibrium outcomes of this game are summarised in Table 1 (price), Table 2 (quantity) and Table 3 (profit) according to the strategies available to each player.

Firm 2 \ Firm 1	PM	B
PM	$\frac{1-d+w(1-n)}{2-n-d}, \frac{1-d+w(1-n)}{2-n-d}$	$\frac{w(1-n)(1-n+d+\beta)+(1-n)(1-d)+}{(1-n)(2-n)+\beta(2-n-d^2)}$ $\frac{w(1-n)(2-n+\beta d)+\beta[2-n-d(1-n+}{(1-n)(2-n)+\beta(2-n-d^2)}$
B	$\frac{w(1-n)(2-n+\beta d)+\beta[2-n-d(1-n+d)]}{(1-n)(2-n)+\beta(2-n-d^2)}$, $\frac{w(1-n)(1-n+d+\beta)+(1-n)(1-d)+\beta(1-d^2)}{(1-n)(2-n)+\beta(2-n-d^2)}$	$\frac{\beta(1-d)+w(1-n)}{1-n+\beta(1-d)}, \frac{\beta(1-d)+w(1-n)}{1-n+\beta(1-d)}$

Table 1. Equilibrium values of prices under B and PM.

Firm 2 \ Firm 1	PM	B
PM	$\frac{1-w}{(1+d)(2-n-d)}, \frac{1-w}{(1+d)(2-n-d)}$	$\frac{(1-w)[1-n+\beta(1+d)]}{(1+d)[(1-n)(2-n)+\beta(2-n-d^2)]}$, $\frac{(1-w)(2-n+d)}{(1+d)[(1-n)(2-n)+\beta(2-n-d^2)]}$
B	$\frac{(1-w)(2-n+d)}{(1+d)[(1-n)(2-n)+\beta(2-n-d^2)]}$, $\frac{(1-w)[1-n+\beta(1+d)]}{(1+d)[(1-n)(2-n)+\beta(2-n-d^2)]}$	$\frac{1-w}{(1+d)[1-n+\beta(1-d)]}$, $\frac{1-w}{(1+d)[1-n+\beta(1-d)]}$

Table 2. Equilibrium values of quantities under B and PM.

Firm 2 \ Firm 1	PM	B
PM	$\frac{(1-w)^2(1-d)}{(1+d)(2-n-d)^2}, \frac{(1-w)^2(1-d)}{(1+d)(2-n-d)^2}$	$\frac{(1-w)^2(1-d)[1-n+\beta(1+d)]^2}{(1+d)[(1-n)(2-n)+\beta(2-n-d^2)]^2}$, $\frac{\beta(1-w)^2(1-d)(2-n+d)^2}{(1+d)[(1-n)(2-n)+\beta(2-n-d^2)]^2}$
B	$\frac{\beta(1-w)^2(1-d)(2-n+d)^2}{(1+d)[(1-n)(2-n)+\beta(2-n-d^2)]^2}$, $\frac{(1-w)^2(1-d)[1-n+\beta(1+d)]^2}{(1+d)[(1-n)(2-n)+\beta(2-n-d^2)]^2}$	$\frac{\beta(1-w)^2(1-d)}{(1+d)[1-n+\beta(1-d)]^2}, \frac{\beta(1-w)^2(1-d)}{(1+d)[1-n+\beta(1-d)]^2}$

Table 3. Payoff matrix (profits) under B and PM.

Let

$$d_a(\beta,n) := \frac{\sqrt{\beta(2-n)[\beta-(1-n)\sqrt{\beta}]}}{\beta}, \tag{22}$$

$$d_b(\beta,n) := \frac{\sqrt{(1-n+\beta)[\beta-(1-n)\sqrt{\beta}]}}{\beta} \tag{23}$$

and

$$d_c(\beta,n) := 1-\frac{1-n}{\sqrt{\beta}}, \tag{24}$$

be three threshold values of the degree of product differentiation such that the profit differentials $\Delta_a = \Pi_i^{B/PM} - \Pi_i^{PM/PM} = 0$, $\Delta_b = \Pi_i^{PM/B} - \Pi_i^{B/B} = 0$ and $\Delta_c = \Pi_i^{PM/PM} - \Pi_i^{B/B} = 0$, respectively ($i,j = \{1,2\},\ i \neq j$). Let

$$\beta_T := (1-n)^2, \tag{25}$$

be a threshold value of the bargaining power (obtained as a solution for β of $d_a(\beta,n) = d_b(\beta,n) = d_c(\beta,n) = 0$). As a corollary of the expression in (25), one can observe that when $d = 0$ (monopoly) a firm in a network market always finds it convenient to be codetermined, and the higher the strength of the network effect the more likely the monopolist wants to let union representatives sit in the supervisory board. Alternatively, the policy maker should ensure a higher number of union representatives through an ad hoc law. For example, a relatively small network effect ($n \cong 0.25$) is enough to make codetermination profitable until the union representatives are at most equal to firm's representatives on the supervisory board.

The thresholds $d_a(\beta,n)$ and $d_b(\beta,n)$ are binding if and only if $\beta > \beta_T$ for any $0 \leq n < 1$, otherwise they do not apply for meaningful values of both the relative bargaining power of the firm and degree of product differentiation. The shape of $d_a(\beta,n)$ (solid line), $d_b(\beta,n)$ (dashed line) and $d_c(\beta,n)$ (dotted line) is depicted in Panels (a)-(d) of Figure 1 in the parameter space (β,d) for different values of the network strength n. These values are the following: $n = 0$ (no network effects, Panel (a)), $n = 0.3$ (Panel (b)), $n = 0.5$ (Panel (c)) and $n = 0.7$ (Panel (d)). As is clear by looking at the figure, the smaller (resp. larger) the value of the network externality, the smaller (resp. larger) the parameter space (β, d) in which $d_a(\beta, n)$ and $d_b(\beta, n)$ apply. In the limiting case of no network effects, these thresholds are never meaningful for any $0 < \beta \leq 1$ and $-1 < d < 1$. The red point on the β -axis in the different panels of Figure 1 represents the threshold β_T and may help clarifying the working of the network externality in determining the outcomes of the game at *the codetermination stage* (stage 1), where each owner has to choose to be either a codetermined or profit-maximising firm in a price-setting network industry. Indeed, the vertical solid red line starting from the red point separates the area in which codetermination does not emerge (left) from the area in which it can emerge (right) as a market outcome depending on the relative size of β and d. To this purpose, Propositions 1, 2 and 3, and Corollary 1 show the different spectrum of equilibrium outcomes of this two-stage game and highlight the important role of the strength of the network externality in letting codetermination emerge as a Nash equilibrium.

Proposition 1. Let $\beta < \beta_T$ hold. [Product substitutability]. (1) If $1 > d > 0$ then (PM,PM) is the unique Pareto efficient SPNE of the game (deadlock). [Product complementarity]. (2) If $0 > d > -d_c(\beta, n)$ then (PM,PM) is the unique Pareto efficient SPNE of the game (deadlock). (3) If $-d_c(\beta, n) > d > -1$ then (PM,PM) is the unique Pareto inefficient SPNE of the game (prisoner's dilemma).

Proposition 2. Let $\beta > \beta_T$ hold. [Product substitutability]. (1) If $1 > d > d_b(\beta, n)$ then (PM,PM) is the unique Pareto efficient SPNE of the game (deadlock). (2) If $d_b(\beta, n) > d > d_a(\beta, n)$ then there exist two pure-strategy Nash equilibria given by (B,B) and (PM,PM), and PM payoff dominates B (coordination game). (3) If $d_a(\beta, n) > d > d_c(\beta, n)$ then (B,B) is the unique Pareto inefficient SPNE of the game (prisoner's dilemma). (4) If $d_c(\beta, n) > d > 0$ then (B,B) is the unique Pareto efficient SPNE of the game (deadlock). [Product complementarity]. (5) If $0 > d > -d_a(\beta, n)$ then (B,B) is the unique Pareto efficient SPNE of the game (deadlock). (6) If

$-d_a(\beta,n) > d > -d_b(\beta,n)$ then there exist two pure-strategy Nash equilibria given by (B,B) and (PM,PM), and B payoff dominates PM (coordination game). (7) If $-d_b(\beta,n) > d > -1$ then (PM,PM) is the unique Pareto inefficient SPNE of the game (prisoner's dilemma).

Corollary 1. If $n = 0$ (no network effects) then (B,B) does never emerge as a Nash equilibrium of the game.

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

$$\Delta_a = \frac{(1-w)^2(1-d)(1-\beta)[\beta d^4-2\beta(2-n)d^2-n^4+6n^3-(13-\beta)n^2+4(3-\beta)n-4(1-\beta)]}{(1+d)(2-n-d)^2[(1-n)(2-n)+\beta(2-n-d^2)]^2},$$

$$\Delta_b = \frac{(1-w)^2(1-d)(1-\beta)}{(1+d)[1-n+\beta(1-d)]^2[(1-n)(2-n)+\beta(2-n-d^2)]^2}\times$$

$$\times[-\beta^3d^4+2\beta^2(1+\beta-n)d^2+\beta n^2(5+\beta-2n)+(1+\beta)(1-\beta^2)-n^3(4-n)+6n^2-4n(1+\beta)],$$

and

$$\Delta_c = \frac{(1-w)^2(1-d)(1-\beta)[(1-n)^2-\beta+\beta d(2-d)]}{(1+d)(2-n-d)^2[1-n+\beta(1-d)]^2}.$$

The sign of Δ_a, Δ_b and Δ_c change depending on the relative size of d, β and n. Let us consider first the case $\beta < \beta_T$. (1) If $1 > d > 0$ then $\Delta_a < 0$, $\Delta_b > 0$ and $\Delta_c > 0$. (2) If $0 > d > -d_c(\beta,n)$ then $\Delta_a < 0$, $\Delta_b > 0$ and $\Delta_c > 0$. (3) If $-d_c(\beta,n) > d > -1$ then $\Delta_a < 0$, $\Delta_b > 0$ and $\Delta_c < 0$. Therefore, Proposition 1 follows. Let us consider now the case $\beta > \beta_T$. (1) If $1 > d > d_b(\beta,n)$ then $\Delta_a < 0$, $\Delta_b > 0$ and $\Delta_c > 0$. (2) $d_b(\beta,n) > d > d_a(\beta,n)$ then $\Delta_a < 0$, $\Delta_b < 0$ and $\Delta_c > 0$. (3) If $d_a(\beta,n) > d > d_c(\beta,n)$ then $\Delta_a > 0$, $\Delta_b < 0$ and $\Delta_c > 0$. (4) If $d_c(\beta,n) > d > 0$ then $\Delta_a > 0$, $\Delta_b < 0$ and $\Delta_c < 0$. (5) If $0 > d > -d_a(\beta,n)$ then $\Delta_a > 0$, $\Delta_b < 0$ and $\Delta_c < 0$. (6) If $-d_a(\beta,n) > d > -d_b(\beta,n)$ then $\Delta_a < 0$, $\Delta_b < 0$ and $\Delta_c < 0$. (7) If $-d_b(\beta,n) > d > -1$ then $\Delta_a < 0$, $\Delta_b > 0$ and $\Delta_c < 0$. Therefore, Proposition 2 follows. If $n = 0$ then $\beta_T = 1$ and $\beta \leq \beta_T$

holds for $0 < \beta \leq 1$. Therefore, depending on the relative size of d, the outcome of the game is given by one of the points of Proposition 1 and Corollary 1 holds. **Q.E.D.**

Proposition 3. An increase in n monotonically reduces the threshold value β_T. An increase in β (or in n) monotonically increases the threshold values $d_a(\beta, n)$ and $d_b(\beta, n)$ such that $\Delta_a = 0$ and $\Delta_b = 0$, respectively, for any $\beta_T < \beta \leq 1$ and $0 < n < 1$. An increase in β (or in n) monotonically increases the threshold value $d_c(\beta, n)$ such that $\Delta_c = 0$ for any $0 < \beta \leq 1$ and $0 < n < 1$.

Proof. The proof easily follows by looking at the sign of first order derivatives of the different thresholds with respect to β and n. **Q.E.D.**

Proposition 1-3 give us an intuitive policy suggestion for the (voluntary) emergence of codetermination. As the strength of the network effect increases, the need for the union to bargain aggressively for achieving its goals becomes less important as a larger value of n contributes per se to increase employment (and thus production and profits). The need for less aggressive union behaviour leads firms agreeing to bargain with them easily. Product differentiation also works for making the occurrence of codetermination more likely: other things being equal, an increase in the degree of product differentiation increases the market power of firms and thus their profits, leading employers' representatives to bargain with employees' representatives for a broader range of values of union relative bargaining power at the equilibrium. As an increase in the degree of product differentiation results in higher employment and profits for the firm, and this effect is amplified by the network externality, the emergence of (B,B) as a Nash equilibrium is due to the union behaviour that does not need to bargain aggressively to get its own will so that each firm can more easily accept a unionised labour market unilaterally, that is B becomes the dominant strategy for each firm. Moreover, and more importantly, when (for a given n) the product is sufficiently differentiated, the increase in employment and profits under codetermination is such that (B,B) becomes the Pareto efficient Nash equilibrium market outcome of the game. Therefore, as far as n increases, PM continues to be the dominant strategy only when unions can bargain aggressively with firm's owners ($\beta \downarrow$). In that case, codetermination can emerge only through mandatory requirements.

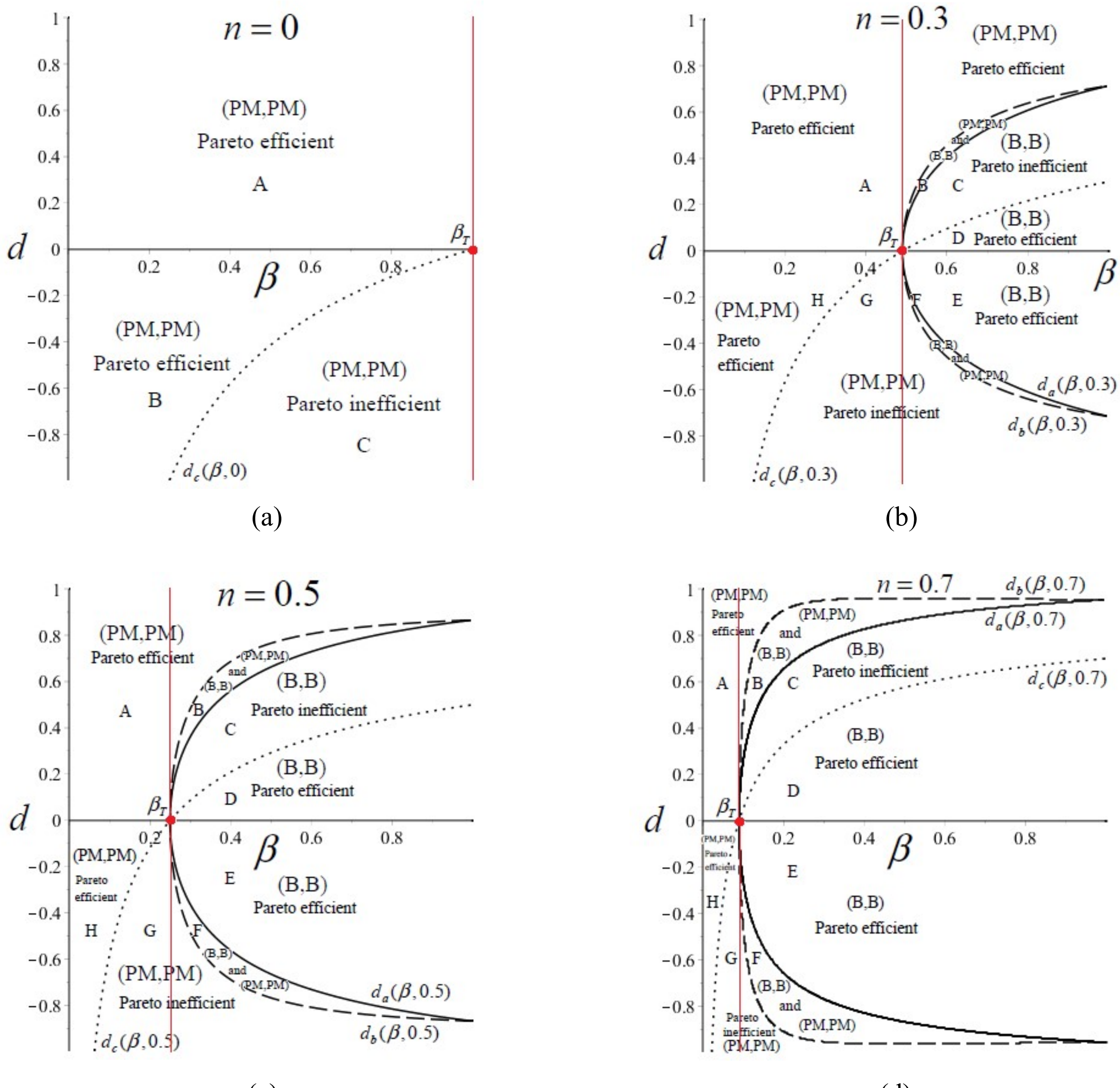

Figure 1. Codetermination and network externalities in a price-setting duopoly with homogeneous bargaining effort. Nash equilibrium outcomes in (β, d) plane for different values of n. The solid (resp. dashed) [resp. dotted] line represents the threshold value $d_a(\beta, n)$ (resp. $d_b(\beta, n)$) [resp. $d_c(\beta, n)$] related to the profit differential $\Delta_a = 0$ (resp. $\Delta_b = 0$) [resp.$\Delta_c = 0$]. Panel (a): $n = 0$. Panel (b): $n = 0.3$. Panel (c): $n = 0.5$. Panel (d): $n = 0.7$.

So far, we have identified the critical role of n in determining (with the favour of both a small degree of product differentiation and a small union's bargaining power) the emergence of codetermination as a Nash equilibrium in a price-setting duopoly. Now, we investigate the mechanisms through which the network effect leads to that outcome. For doing this, we must disentangle the effects on market price, quantity and profits due to changes in the parameters of interest and provide the economic intuition behind these results detailed in the proposition above by dividing for the cases of non-network and network industries.

Non-network industry ($n = 0$). Let us begin the discussion by starting from a situation where products are substitutes ($d = 0.5$), so that prices are strategic complement, and unions bargain not too much aggressively with firms ($\beta = 0.8$) in the price setting (see Table 4). Assume now an increase in the bargaining power of unions up to near-parity, $\beta = 0.5$ (see Table 5). This causes a reduction in the market price and an increase in employment when both firms are codetermined (see Table 4 versus Table 5). The negative effect on profits of the reduction in the price is larger than the positive effect due to the increased employment and then profits of both codetermined firms reduce. This outcome also holds to the B-firm in the case of asymmetric behaviour. However, the PM-firm undergoes a reduction in both price and quantity so that its profits monotonically reduce when the union of the codetermined rival becomes more aggressive in the bargaining. Differently, the price of the B-firm goes down and its quantity goes up substantially, according to the union's will. However, the positive effect on profits due to the increased production is never strong enough to offset the negative effect due to the corresponding reduction in the market price for the B-firm. This implies that the profit of every firm is reducing when the union bargaining power is shocked positively when both firms are codetermined as well as in the case of asymmetric behaviour. However, the relatively larger reduction in the profits of the PM-firm is never strong enough to let it deviate towards B. Definitely, PM is a dominant strategy for any $0 < \beta \leq 1$ (we recall that if $n = 0$

then $\beta_T = 1$ and the thresholds $d_a(\beta, n)$ and $d_b(\beta, n)$ do never apply) and the Nash equilibrium (PM,PM) is Pareto efficient (deadlock). This result is clearly shown by comparing the examples reported in Table 4 and Table 5 representing the equilibrium values of market price (Panel a), quantity (Panel b) and equilibrium outcomes (payoff matrix) (Panel c) of an increase in the bargaining power of the union in a non-network industry.

We now consider the case of product complementarity. Intuitively, on one hand it may be expected that the presence of unions of its own reduces firms' profits; on the other hand, however, since the game is played in strategic substitutes in this case, it is straightforward that when prices are reducing, and quantities are increasing profits will tend to increase. This implies that it could be more profitable for both firms to be codetermined (i.e., to be forced to increase production). While in the absence of codetermination the unique (PM,PM) equilibrium always implies that there is a prisoner's dilemma, if the union increases its bargaining power profits tend to sharply decline when product complementarity is little and become lower than in the absence of the union, though the union bargaining unit tends to increase employment. This is because the positive effect of the union behaviour on employment is transferred to both firms through the working of the degree of product complementarity; this holds to the extent that the negative effect of the reduction in profits due to the presence of unions is counterbalanced by the positive effect of the increase in production that unions cause: in other words, provided that the degree of complementarity is sufficiently high, the increase in employment/production due to the union effect (thanks to intensity of the complementarity effect) allows profits under (B,B) to be higher than profits under (PM,PM). Differently, if the degree of product complementarity is sufficiently small, the positive complementarity effect is not high enough to overweight the negative profit effect due to the presence of unions (i.e., profits under (B,B) are lower than profits under (PM,PM)) and thus the from a prisoner's dilemma the game becomes a deadlock.

It may be instructive now to look at what happens when the degree of product differentiation increases while keeping constant the union power at the near-parity level $\beta = 0.5$, for understanding whether and how a sufficiently low degree of complementarity under codetermination may eliminate the prisoner's dilemma and restore Pareto efficiency. For illustrative purposes, we consider the case of $d = -0.2$ (low degree of product complementarity). Then, Table 6 shows that although firms have an advantage of behaving as if they had to cooperate by increasing prices and production, the degree of product complementarity can never be high enough to let profits of the B-firm be larger than those of the PM rival under asymmetric behaviour. This implies that the PM-firm does not have an incentive to deviate towards B, so that PM is the dominant strategy and (PM,PM) is the unique efficient Nash equilibrium as in the case of product substitutability. However, from a deadlock game firms can be entrapped in a prisoner's dilemma if products are sufficiently complementary. For instance, we assume $d = -0.7$ (Table 7) and compare this case with the previous one (Table 6 versus Table 7). The tables show that when $d = -0.2$ profits under (PM,PM) are larger than the corresponding values under (B,B), whereas when $d = -0.7$ the opposite holds. This is because an increase in the degree of complementarity causes an increase in prices, quantities and profits under PM and B, but profits under B increase more than under PM (indeed, the percentage increase in both price and quantity of the B-firm are larger than those of the PM-firm). Therefore, firms have an incentive to coordinate to play B, but no one has a unilateral incentive to deviate from PM. Indeed, the firm that is playing PM when the other is playing B does never find it convenient to deviate towards B.

To sum up, codetermination can be implemented only by ad hoc legislation (e.g., the German Codetermination Act of 1976) in non-network markets, but when products are complementary mandatory codetermination may be efficient for firms provided that the degree of complementarity is sufficiently low.

Firm 2 / Firm 1	PM	B
PM	0.333, 0.333	0.644, 0.336
B	0.336, 0.644	0.285, 0.285

(b)

(a)

Firm 2 / Firm 1	PM	B
PM	0.444, 0.444	0.431, 0.49
B	0.49, 0.431	0.476, 0.476

Firm 2 / Firm 1	PM	B
PM	0.148, 0.148	0.139, 0.144
B	0.144, 0.139	0.136, 0.136

(c)

Table 4. Price (a), quantity (b) and payoff matrix (profits) (c) under B and PM when $w = 0$, $n = 0$, $d = 0.5$ and $\beta = 0.8$. Deadlock: (PM,PM) is the unique Pareto efficient SPNE of the game ($\Delta_a < 0$, $\Delta_b > 0$ and $\Delta_c > 0$).

Firm 2 / Firm 1	PM	B
PM	0.444, 0.444	0.405, 0.579
B	0.579, 0.405	0.533, 0.533

(a)

Firm 2 / Firm 1	PM	B
PM	0.333, 0.333	0.304, 0.217
B	0.217, 0.304	0.2, 0.2

(b)

Firm 2 / Firm 1	PM	B
PM	0.148, 0.148	0.123, 0.126
B	0.126, 0.123	0.106, 0.106

(c)

Table 5. Price (a), quantity (b) and payoff matrix (profits) (c) under B and PM when $w = 0$, $n = 0$, $d = 0.5$ and $\beta = 0.5$. Deadlock: (PM,PM) is the unique Pareto efficient SPNE of the game ($\Delta_a < 0$, $\Delta_b > 0$ and $\Delta_c > 0$).

Firm 2 / Firm 1	PM	B
PM	0.568, 0.568	0.587, 0.755
B	0.755, 0.587	0.781, 0.781

(a)

Firm 2 / Firm 1	PM	B
PM	0.545, 0.545	0.563, 0.362
B	0.362, 0.563	0.375, 0.375

(b)

Firm 2 / Firm 1	PM	B
PM	0.309, 0.309	0.331, 0.273
B	0.273, 0.331	0.292, 0.292

(c)

Table 6. Price (a), quantity (b) and payoff matrix (profits) (c) under B and PM when $w = 0$, $n = 0$, $d = -0.2$ and $\beta = 0.5$. Deadlock: (PM,PM) is the unique Pareto efficient SPNE of the game ($\Delta_a < 0$, $\Delta_b > 0$ and $\Delta_c > 0$).

Firm 2 / Firm 1	PM	B
PM	1.23, 1.23	1.39, 1.57
B	1.57, 1.39	1.8, 1.8

(a)

Firm 2 / Firm 1	PM	B
PM	0.629, 0.629	0.709, 0.401
B	0.401, 0.709	0.459, 0.459

(b)

Firm 2 / Firm 1	PM	B
PM	0.777, 0.777	0.987, 0.63
B	0.63, 0.987	0.827, 0.827

(c)

Table 7. Price (a), quantity (b) and payoff matrix (profits) (c) under B and PM when $w = 0$, $n = 0$, $d = -0.7$ and $\beta = 0.5$. Prisoner's dilemma: (PM,PM) is the unique Pareto inefficient SPNE of the game ($\Delta_a < 0$, $\Delta_b > 0$ and $\Delta_c < 0$).

Network industry ($n > 0$). The effects of the network externality on equilibrium outcomes of the game are relevant and deserve an ad hoc discussion. The degree of network effects, n, plays a twofold role on firms' profits under B and PM. First, the larger the network, the larger the market size, which in turn causes an outward shift in the demand curve implying an increase in the market price for any given value of the quantity produced under B and PM. This is because each consumer in a network market benefits from the (positive) experience of the other consumers and then he is willing to pay more than in a corresponding non-network setting (for instance, the increase in the size of the network can increase the usefulness of the product for each consumer). Second, the quantity produced in a network industry by each firm is larger than the quantity produced in a corresponding non-network setting. Therefore, the union's will can be achieved less aggressively than when there are no network effects because employment is already high, and each firm is willing to bargain the price directly (and employment indirectly) with its corresponding union bargaining unit. Interestingly, though n exerts the same qualitative role on firms' profits in both cases of codetermination and profit maximisation, there are remarkable differences from a quantitative point of view. In fact, a positive value of n allows the thresholds $d_a(\beta, n)$ and $d_b(\beta, n)$ to come into play in the geometric space (β, d) (see the discussion at the end of Proposition 3). As Panels (b)-(d) in Figures 1 show, when the power of the unions is sufficiently high in the bargaining on prices ($\beta < \beta_T$), $d_a(\beta, n)$ and $d_b(\beta, n)$ are not binding and owners will prefer to be profit maximisers rather than become bargainers under codetermination, as they would reduce profits by choosing to play B. Therefore, the economic mechanisms behind the results when $\beta < \beta_T$ are the same as those discussed above in a non-network setting. Differently, when the power of the unions is sufficiently small ($\beta > \beta_T$), the two thresholds $d_a(\beta, n)$ and $d_b(\beta, n)$ are binding and owners may choose to become bargainers under codetermination. Now, we perform a sensitivity analysis with respect to the occurrence of the type of the Nash equilibrium and its efficiency properties by letting the parameters of interest (d and n) vary. This allows showing how firms' profits change and then which kind of paradigm (prisoner's dilemma, coordination game, Pareto efficient solution) emerges at the first stage of the game. First, we set $w = 0$, $n = 0.5$ and $\beta = 0.5$ (near-parity) and let the degree of product differentiation (d) change. Then, we consider the case of product substitutability (prices are strategic complements) and let d vary from 0.9 to 0.2 (these examples are only for illustrative purposes and are reported in Tables 8-11). If products are perceived as highly substitutable ($d = 0.9$, Table 8) firms do not have an incentive to become bargainers under codetermination. This is because products are close to be perfect substitutes, the degree of competition between firms is high, PM is the dominant strategy and the SPNE of the game is Pareto efficient. Each union bargaining unit must exert relatively high pressure in the bargaining on prices for achieving its goal in term of employment, and then each firm is not prone to increase employment (i.e., reduce the market price) to avoid a sharp reduction in profits due to the high substitutability of products. In thie case, the negative effect on profits of the reduction in the market price overcomes the positive effect of the increased production under codetermination. If the degree of product differentiation increases ($d = 0.7$, Table 9), firms increase profits because their market power becomes larger (firms reduce production and the marginal willingness to pay of consumers increases, ceteris paribus). Interestingly, the increase in profits under B (due to the sharp increase in the market price of the codetermined firm) is large enough to prevent PM being the dominant strategy, i.e. each firm has a unilateral incentive to play the same strategy of the rival (coordination game) but PM payoff dominates B. A further increase in product differentiation ($d = 0.5$, Table 10) changes again the nature of the game that becomes a prisoner's dilemma, where (B,B) is the Pareto inefficient equilibrium outcome (product differentiation works out in the same direction as codetermination by increasing market price and reducing production). However, firms are entrapped in a dilemma because they would have an incentive to coordinate to play profit maximisation, but no one has a unilateral incentive to deviate from codetermination. Finally, when products are slightly substitutable ($d = 0.2$, Table 11), each firm is close to be a monopolist with a large market power and the dilemma is solved as (B,B) becomes the unique Pareto efficient outcome. In fact, when d reduces the increase in the market price under B is larger than the increase in the market price under PM (note that production under B increases due to the working of codetermination whereas production under PM reduces) so that profits in the former case become larger than profits in the latter case. These effects are magnified by further increases in the strength of the network effects. Results are illustrated in Panels (b)-(d) of Figure 1, where n raises from 0.3 to 0.7. As can easily be seen by looking at the figures, the area in the plane (β, d) where (B,B) emerges as the Pareto efficient outcome increases with n.

The economic reason can be ascertained by means of a numerical example taken from Figure 1. Let us consider the case of near-parity ($\beta = 0.5$) and half a degree of product substitutability ($d = 0.5$). Then, let n increase from 0 to 0.7. If $n = 0$, firms have a mutual incentive to be profit maximisers (Pareto efficient outcome) as if both firms chose to deviate towards B, codetermination would increase the quantity by about 24% (from $q_i^{PM/PM} = 0.44$ to $q_i^{B/B} = 0.53$) but would decrease the price by 39% (from $p_i^{PM/PM} = 0.33$ to $p_i^{B/B} = 0.2$), so that profits would be reduced by about 28% (from $\Pi_i^{PM/PM} = 0.14$ to $\Pi_i^{B/B} = 0.1$). If $n = 0.5$ (we skip the case $n = 0.3$ as for the chosen values of d and β the Nash equilibrium is still (PM,PM)) and compare it with the case $n = 0$. Prices and quantities when both firms are profit maximisers ($p_i^{PM/PM}$ and $q_i^{PM/PM}$) increase by about 51.5% (from 0.33 to 0.5) and 50% (from 0.44 to 0.66) respectively, so that profits grow almost by 135% (from 0.14 to 0.33). Differently, prices and quantities when both firms are codetermined ($p_i^{B/B}$ and $q_i^{B/B}$) increase by about 50% (from 0.2 to 0.33) and 66% (from 0.53 to 0.88) respectively, so that profits grow almost by 190% (from 0.1 to 0.29). In the case of mixed behaviour (firm 1 plays B and firm 2 plays PM), price and quantity of B-firm 1 ($p_1^{B/PM}$ and $q_1^{B/PM}$) increases by about 71% and 70% (from 0.21 to 0.36 and from 0.57 to 0.969) respectively, so that

$\Pi_1^{B/PM}$ increases by about 177% passing from 0.126 to 0.35, whereas price and quantity of PM-firm 2 ($p_2^{B/PM}$ and $q_2^{B/PM}$) both increase by about 50% (from 0.3 to 0.45 and from 0.4 to 0.6) , so that $\Pi_2^{B/PM}$ increases by about 119% passing from 0.123 to 0.27. The strength of the network effect when $n = 0.5$ generates an increase in prices, quantities and profits in both cases of symmetric and asymmetric behaviours so that B becomes the dominant strategy of the game (this is because profits of B-firm 1 becomes larger than those of the rival PM-firm 2). However, as $\Pi_i^{PM/PM}$ (0.14) were higher than $\Pi_i^{B/B}$ (0.1) when $n = 0$, the percentage increase in prices, quantities and profits when $n = 0.5$ are such that both firms have a mutual incentive to play PM but no one has a unilateral incentive to deviate from B, so that (B,B) becomes the Pareto inefficient Nash equilibrium of the game (prisoner's dilemma), where $\Pi_i^{PM/PM} = 0.33$ and $\Pi_i^{B/B} = 0.29$. Finally, let un consider a further increase in the network effect ($n = 0.7$). B is still the dominant strategy of the game. The only difference with the case $n = 0.5$ is that the percentage increase in prices and quantities when both firms play B (36% and 38%, respectively) is larger than the percentage increase in prices and quantities when both firms play PM (25% and 26%, respectively). This results in a percentage increase in $\Pi_i^{PM/PM}$ and $\Pi_i^{B/B}$ of almost 57% (from 0.33 to 0.52) and 90% (from 0.29 to 0.55), respectively, so that (B,B) becomes the Pareto efficient outcome of the game. To sum up, for a given value of the wage (w), the degree of product differentiation (d) and the relative bargaining power (β), the strength of the network effect (n) is capable per se to make it convenient moving from PM to B. Moreover, the higher the strength of the network effect, the more likely the B equilibrium will also be efficient.

Our policy suggestions therefore are the following: in a non-network market, codetermination does never emerge as a market outcome and then it may be set only through an ad hoc legislation. In the latter case, it would represent a Pareto improving institution only when products are (not to highly) complementary. In this case, firms may decide to locate their own plants in a region (for instance, Germany) where codetermination is mandatory. Differently, voluntary codetermination shows promises in network markets. In this case, we argue that it is in the self-interest of firms' owners determining the condition to bargain on employment. This kind of codetermination may represent an application of the theoretical suggestions proposed by Furubotn (1988) about voluntary contractual agreements on codetermination, which are generally independent on the number of employees (see also the discussion on this issue in Osterloh et al., 2011).

Firm 1 \ Firm 2	PM	B
PM	0.877, 0.877	0.696, 1.153
B	1.153, 0.696	0.956, 0.956

(a)

Firm 1 \ Firm 2	PM	B
PM	0.166, 0.166	0.132, 0.109
B	0.109, 0.132	0.09, 0.09

(b)

Firm 1 \ Firm 2	PM	B
PM	0.146, 0.146	0.09, 0.12
B	0.12, 0.09	0.08, 0.08

(c)

Table 8. Price (a), quantity (b) and payoff matrix (profits) (c) under B and PM when $w = 0, n = 0.5, \beta = 0.5$ and $d = 0.9$. Deadlock: (PM,PM) is the unique Pareto efficient SPNE of the game ($\Delta_a < 0, \Delta_b > 0$ and $\Delta_c > 0$).

Firm 1 \ Firm 2	PM	B
PM	0.735, 0.735	0.63, 1.03
B	1.03, 0.63	0.904, 0.904

(a)

Firm 1 \ Firm 2	PM	B
PM	0.375, 0.375	0.322, 0.262
B	0.262, 0.322	0.23, 0.23

(b)

Firm 1 \ Firm 2	PM	B
PM	0.275, 0.275	0.204, 0.271
B	0.271, 0.204	0.208, 0.208

(c)

Table 9. Price (a), quantity (b) and payoff matrix (profits) (c) under B and PM when $w = 0, n = 0.5, \beta = 0.5$ and $d = 0.7$. Coordination game: (PM,PM) and (B,B) are the Nash equilibria of the game in pure strategies ($\Delta_a < 0$, $\Delta_b < 0$ and $\Delta_c > 0$).

Firm 1 \ Firm 2	PM	B
PM	0.66, 0.66	0.606, 0.969
B	0.969, 0.606	0.88, 0.88

(a)

Firm 1 \ Firm 2	PM	B
PM	0.5, 0.5	0.454, 0.363
B	0.363, 0.454	0.33, 0.33

(b)

Firm 1 \ Firm 2	PM	B

PM	0.33, 0.33	0.27, 0.35
B	0.35, 0.27	0.29, 0.29

(c)

Table 10. Price (a), quantity (b) and payoff matrix (profits) (c) under B and PM when $w = 0$, $n = 0.5$, $\beta = 0.5$ and $d = 0.5$. Prisoner's dilemma: (B,B) is the unique Pareto inefficient SPNE of the game ($\Delta_a > 0$, $\Delta_b < 0$ and $\Delta_c > 0$).

Firm 1 \ Firm 2	PM	B
PM	0.64, 0.64	0.61, 0.95
B	0.95, 0.61	0.92, 0.92

(a)

Firm 1 \ Firm 2	PM	B
PM	0.61, 0.61	0.59, 0.45
B	0.45, 0.59	0.44, 0.44

(b)

Firm 1 \ Firm 2	PM	B
PM	0.39 0.39	0.36, 0.43
B	0.43, 0.36	0.41, 0.41

(c)

Table 11. Price (a), quantity (b) and payoff matrix (profits) (c) under B and PM when $w = 0$, $n = 0.5$, $\beta = 0.5$ and $d = 0.2$. Deadlock: (B,B) is the unique Pareto efficient SPNE of the game ($\Delta_a > 0$, $\Delta_b < 0$ and $\Delta_c < 0$).

4. Endogenous codetermination

The results obtained in the previous section allow to have some policy recipes (mandatory codetermination versus voluntary codetermination) depending on the values of the main parameters of the problem. However, one of the drawbacks of the proposed approach (following the original idea of Kraft, 1998) lies in the fact that the degree of codetermination (i.e., the strength with which trade unions negotiate with firms) is an exogenous parameter $(1 - \beta)$. Differently, firms might decide to bargain not with any trade union, but with the one just allowing to maximise their own profits. Indeed, in actual economies there may be different types of union bargaining units that should not necessarily be appreciated by the firm as part of the bargaining process. To overcome this gap and accounting for this heterogeneity, this section speculates in this direction and extends the model previously developed with an exogenous degree of codetermination by assuming that each firm is aware of the union's attitude at the time of bargaining and chooses to bargain with a union bargaining unit under codetermination only whether the firm's bargaining power is the profit-maximising one. In doing this, *we assume that the firm has the right to choose the composition of* *the board of representatives (including or not workers' representatives) making production decisions*. This amounts to say that firms may choose the optimal union's bargaining effort by choosing the optimal corresponding number of workers' representative to be co-opted within the supervisory board.

Let us first assume the existence of a continuum of firm-specific unions differentiated amongst them based on their relative attitude to bargain ($0 < 1 - \beta_i \leq 1$). The research question, which is novel at the best of our knowledge, arising in this context is the following: do firms always prefer to bargain with a trade union with a little bargaining power? The answer is not so obvious, and the aim of this section is to show that the strategic interacting effects between the degree of product differentiation and the strength of the network effect may lead a price-setting duopoly firm to bargain with a union-unit with a sizeable bargaining power, as this choice allows a firm to maximise its own profit. This result does not hold in a non-network industry ($n = 0$).

The stages of the game change and become the following. At stage 1 (*the codetermination stage*), each owner must choose to be either a codetermined or profit-maximising firm. At stage 2 (*the union-strength stage*) the owner of each firm chooses to bargain with a union bargaining unit only whether its bargaining attitude is exactly the profit-maximising one. At stage 3 (*the bargaining market stage*), firms either choose the price in the output market in the case of profit maximisation or bargain it together with unions in the case of codetermination. The game follows the backward induction logic. We now briefly discuss the main features of a network-codetermination non-cooperative (three-stage) game with price competing firms, complete information and endogenous codetermination. Of course, equilibrium outcomes are still those reported in the expressions (11)-(13) if both firms are profit maximising (PM) so that $\beta_1 = \beta_2 = 1$. When both firms are codetermined (B), the Nash bargaining function Eq. (6) modifies to become $N_i = \Pi_i^{\beta_i} Z_i^{1-\beta_i}$. This implies that firm 1 bargains with type-1 union with an effort or bargaining strength β_1 to set the price of product of variety 1. Correspondingly, firm 2 bargains with type-2 union with an effort or bargaining strength β_2 to set the price of product of variety 2. Then, there will be prices and quantities as a function of β_1 and β_2 that should be used to compute profits of firm i ($i, j = \{1,2\}$, $i \neq j$), that is:

$$\overline{\Pi}_i^{B/B} = \frac{\beta_i(1-w)^2(1-d)[1-n+\beta_j(1+d)]^2}{(1+d)[(1-n)^2+(1+n)(\beta_i+\beta_j)-(1-d^2)\beta_i\beta_j]^2}. \tag{26}$$

As each firm chooses to bargain with its own union if and only if there exists a profit-maximising bargaining power, we get the following *reaction-bargaining-function* of firm i, that is:

$$\frac{\partial \overline{\Pi}_i^{B/B}}{\partial \beta_i} = 0 \Leftrightarrow \beta_i(\beta_j) = \frac{(1-n)(1-n+\beta_j)}{1-n+\beta_j(1-d^2)}. \tag{27}$$

By using the corresponding counterpart version of (27) for firm j, one can get the *optimal value of firm i's bargaining strength* (outcomes are symmetric), that is

$$\beta_i^{*(B/B)} = \frac{1-n}{\sqrt{1-d^2}}, \quad i,j = \{1,2\}. \tag{28}$$

The expression in (28) gives all the couples (n, d) such that the owner maximises profits by choosing to be bargainer under codetermination and it is meaningful if and only if $\beta_i^{*(B/B)} \leq 1$. Therefore, this implies that

$$n \geq n_\beta(d) := 1 - \sqrt{1-d^2}, \tag{29}$$

should hold, otherwise there would be no economically meaningful profit-maximising value of β_i, meaning that each firm would decide to be codetermined by choosing a profit-maximising bargaining effort if and only if the network externality is strong enough, otherwise each firm would prefer to be a profit-maximiser.[12]

By substituting out (28) into (26) for β_i one gets profits of firm i under optimal codetermination, that is

$$\Pi_i^{B/B} = \frac{(1-w)^2(1-d)(1+d+\sqrt{1-d^2})^2}{4(1-n)(1+d)(1-d^2+\sqrt{1-d^2})^2}. \tag{30}$$

[12] With no networks, firms always find it convenient to be profit maximisers (in line with the results of Section 3).

When firm 1 is codetermined (B) and firm 2 is profit maximiser (PM), firm 1 bargains with type-1 union with an effort β_1 and firm 2 does not bargain at all ($\beta_2 = 1$). Then, by considering prices and quantities as a function of β_1 profits of firm 1 and firm 2 are the following:

$$\overline{\Pi}_1^{B/PM} = \frac{\beta_1(1-w)^2(1-d)(2-n+d)^2}{(1+d)[2-3n+n^2+\beta_1(2-n-d^2)]^2}. \tag{31}$$

and

$$\overline{\Pi}_2^{B/PM} = \frac{(1-w)^2(1-d)[1-n+\beta_1(1+d)]^2}{(1+d)[2-3n+n^2+\beta_1(2-n-d^2)]^2}. \tag{32}$$

The profit-maximising bargaining power β_1 is the following:

$$\frac{\partial\overline{\Pi}_1^{B/PM}}{\partial\beta_1} = 0 \Leftrightarrow \beta_1^{*(B/PM)} = \frac{(1-n)(2-n)}{2-n-d^2} < 1. \tag{33}$$

By substituting out (33) into (31) and (32) for β_1 one gets

$$\Pi_1^{B/PM} = \frac{(1-w)^2(1-d)(2-n+d)^2}{4(1-n)(2-n)(1+d)(2-n-d^2)}. \tag{34}$$

and

$$\Pi_2^{B/PM} = \frac{(1-w)^2(1-d)[2-n-d^2+(2-n)(1+d)]^2}{4(2-n)^2(1+d)(2-n-d^2)^2}. \tag{35}$$

To sum up, Table 12 summarises the equilibrium outcomes of the optimal bargaining strength in the cases of both symmetric and asymmetric behaviours and Table 13 refers to the corresponding values of firms' profits (payoff matrix).

Firm 2 / Firm 1	PM	B
PM	1,1	$1, \frac{(1-n)(2-n)}{2-n-d^2}$
B	$\frac{(1-n)(2-n)}{2-n-d^2}, 1$	$\frac{1-n}{\sqrt{1-d^2}}, \frac{1-n}{\sqrt{1-d^2}}$

Table 12. Endogenous codetermination. Equilibrium values of the bargaining strength under B and PM. The optimal firm's bargaining strength under (B,B) are meaningful if and only if $n \geq n_\beta(d)$.

Firm 2 / Firm 1	PM	B
PM	$\frac{(1-w)^2(1-d)}{(1+d)(2-n-d)^2}, \frac{(1-w)^2(1-d)}{(1+d)(2-n-d)^2}$	$\frac{(1-w)^2(1-d)[2-n-d^2+(2-n)(1+d)]^2}{4(2-n)^2(1+d)(2-n-d^2)^2}$, $\frac{(1-w)^2(1-d)(2-n+d)^2}{4(1-n)(2-n)(1+d)(2-n-d^2)}$
B	$\frac{(1-w)^2(1-d)(2-n+d)^2}{4(1-n)(2-n)(1+d)(2-n-d^2)}$, $\frac{(1-w)^2(1-d)[2-n-d^2+(2-n)(1+d)]^2}{4(2-n)^2(1+d)(2-n-d^2)^2}$	$\frac{(1-w)^2(1-d)(1+d+\sqrt{1-d^2})^2}{4(1-n)(1+d)(1-d^2+\sqrt{1-d^2})^2}$, $\frac{(1-w)^2(1-d)(1+d+\sqrt{1-d^2})^2}{4(1-n)(1+d)(1-d^2+\sqrt{1-d^2})^2}$

Table 13. Endogenous codetermination. Equilibrium values of profits under B and PM (payoff matrix).

Let $n_b^1(d) = n_c^1(d) = 1-\sqrt{1-d^2} = n_\beta(d)$, $n_b^2(d)$ and $n_c^2(d)$ be two threshold values of the strength of the network effect such that the corresponding profit differentials $\Delta_b = \Pi_i^{PM/B} - \Pi_i^{B/B} = 0$ and $\Delta_c = \Pi_i^{PM/PM} - \Pi_i^{B/B} = 0$ $(i,j = \{1,2\},\ i \neq j)$. The shape of $n_\beta(d) = n_b^1(d) = n_c^1(d)$ (solid line), $n_b^2(d)$ (dashed line) and $n_c^2(d)$ (dotted line) is depicted in Figure 2 in the parameter space (n,d).[13] The red region in the figure refers to the couples (n,d) corresponding to which every firm does not find it convenient to bargain with its own union under codetermination. The following proposition classifies the outcomes of the game at *the codetermination stage* (stage 1), where each owner must choose to be either a codetermined or profit-maximising firm under *endogenous codetermination*.

[13] Note that there exists no closed-form expression for $n_b^2(d)$, whereas the expression of $n_c^2(d)$ cannot be dealt with in a neat analytical form. However, this is not relevant for the results of the model with endogenous codetermination as Figure 2 helps clarifying the shapes of the profit differentials.

Proposition 4. [Endogenous codetermination]. Let $n < n_\beta(d)$ hold. Every firm does not find it convenient to bargain with its own firm-specific union under codetermination in both cases of product substitutability and complementarity. Let $n \geq n_\beta(d)$ hold. [Product substitutability]. (1) If $n_\beta(d) < n < n_b^2(d)$ then (B,PM) and (PM,B) are two pure-strategy Pareto efficient Nash equilibria of the game (coordination game). (2) If $n_b^2(d) < n < n_c^2(d)$ then (B,B) is the unique Pareto inefficient SPNE of the game (prisoner's dilemma). (3) If $n_c^2(d) < n < 1$ then (B,B) is the unique Pareto efficient SPNE of the game (deadlock). [Product complementarity]. (4) If $n_\beta(d) < n < 1$ then (B,B) is the unique Pareto efficient SPNE of the game (deadlock).

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

$$\Delta_a = \frac{(1-w)^2(1-d)(2n-n^2-d^2)^2}{4(1-n)(2-n)(1+d)(2-n-d^2)(2-n-d)^2} > 0,$$

$$\Delta_b = \frac{-(1-w)^2(1-d)}{4(1-n)(2-n)(1+d)(2-n-d^2)^2\sqrt{1-d^2}(1+\sqrt{1-d^2})^2} \times$$

$$\{2(1+d)(1+\sqrt{1-d^2})n^4 + [(1-d^2)^{\frac{3}{2}}(2+d)^2 + \sqrt{1-d^2}(4d^3+5d^2-12d-12) - 2(1+d)(4+d^2(1+d))]n^3 +$$

$$+[(1-d^2)^{\frac{3}{2}}(2d^3-d^2-20d-20) + \sqrt{1-d^2}(2d^5+2d^4-22d^3-25d^2 + 28(1+d)) - 2d^5+4d^4+20d^3+14d^2+8(1+d)]n^2 +$$

$$+[(1-d^2)^{\frac{3}{2}}(d^4-6d^3-4d^4+32(1+d)) - \sqrt{1-d^2}(8d^5+7d^4-42d^3 - 44d^2+32(1+d)) - 2d^6+4d^5+2d^4-28d^3-24d^2]n +$$

$$+(1-d^2)^{\frac{3}{2}}(-d^4+4d^3+4d^2-16(1+d)) + \sqrt{1-d^2}(8d^5+7d^4-28d^3-28d^2+16(1+d)) + 2d^6-2d^4+8d^3+8d^2\},$$

and

$$\Delta_c = \frac{-(1-w)^2(1-d)}{2(1+d)(2-n-d)^2(1-n)\sqrt{1-d^2}(1+\sqrt{1-d^2})^2} \times$$

$$\times \{(1+d)(1+\sqrt{1-d^2})n^2 + [(1-d^2)^{\frac{3}{2}} - \sqrt{1-d^2}(2-d-d^2) - d(1+d)]2n$$

$$+$$

$$+\sqrt{1-d^2}(d^3-3d^2+2) + d^2(1+d) - 2(1-d^2)^{\frac{3}{2}}\}.$$

The sign of Δ_b and Δ_c change depending on the relative size of d and n. Let $n < n_\beta(d)$ hold. Then, $\beta_i^{B/B} > 1$ and firm i chooses to do not bargain under codetermination. Let $n \geq n_\beta(d)$ hold. Then, $\beta_i^{B/B} < 1$ and firms may choose to bargain under codetermination. [Product substitutability]. (1) If $n_\beta(d) < n < n_b^2(d)$ then $\Delta_a > 0$, $\Delta_b > 0$ and $\Delta_c > 0$. (2) If $n_b^2(d) < n < n_c^2(d)$ then $\Delta_a > 0$, $\Delta_b < 0$ and $\Delta_c > 0$. (3) If $n_c^2(d) < n < 1$ then $\Delta_a > 0$, $\Delta_b < 0$ and $\Delta_c < 0$. [Product complementarity]. (4) If $n_\beta(d) < n < 1$ then $\Delta_a > 0$, $\Delta_b < 0$ and $\Delta_c < 0$. Therefore, Proposition 4 follows. **Q.E.D.**

Results from Proposition 4 under endogenous codetermination are in line with those obtained in Section 3 under exogenous codetermination. The proposition suggests that the outcome of a network-codetermination game with price-setting firms and optimal codetermination is (B,B) for a wide range of values of both the extent of product differentiation and strength of the network externality. To this purpose, Figure 2 helps clarifying the result of the game. It clearly shows that the larger the degree of product substitutability (resp. complementarity) and the larger the network effect, the lower the optimal bargaining effort of the firm needed to maximise profits. The red area represents the unfeasible parameter space of optimal codetermination, where firms behave as profit maximisers and codetermination can be applied only through legislation. In all other cases, codetermination can emerge through voluntary agreements (irrespective of the number of employees). When prices are strategic substitutes, a voluntary codetermination agreement is efficient. Differently, when prices are strategic complements, it is clear than profits increase with the network effect so that (B,B) is first sub-optimal (prisoner's dilemma) and then efficient for larger values of the externality. In the latter case, firms may have an incentive to locate their plants in a region where codetermination is mandatory as this policy would represent a Pareto superior institution. However, it is possible to have also multiple mixed Nash equilibria corresponding to which only one firm voluntarily chooses to be codetermined. In this case, no one has a dominant strategy and both equilibria are Pareto optimal. The solution of the game may emerge from the credible disclosure of a player's will to do not play B. Then, the rival will be forced to (be the first to) play B to avoid obtaining a lower pay-off unilaterally.

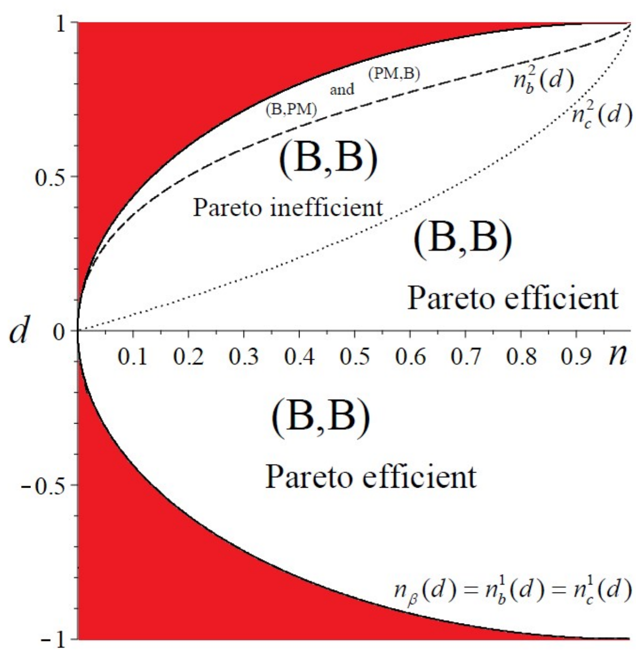

Figure 2. Endogenous codetermination and network externalities in a price-setting duopoly. Nash equilibrium outcomes in (n, d) plane. The dashed (resp. dotted) line represents the threshold value $n_b^2(d)$ (resp. $n_c^2(d)$) related to the profit differential $\Delta_b = 0$ (resp. $\Delta_c = 0$). The black solid line (which is the boundary of the red region representing the unfeasible parameter space of optimal codetermination) is a threshold such that $n_\beta(d) = n_b^1(d) = n_c^1(d)$.

5. Conclusions

Codetermination is part of the European social model and its functioning covers several distinct aspects ranging from workers' protection to employment determination. This article re-examined the existing theoretical literature on employment (co)determination by considering a Bertrand rivalry setting (duopoly) with horizontal product differentiation. In the recent past decades, Kraft (1998, 2001) already showed that quantity-setting firms might have an incentive to voluntarily become bargainers under codetermination rather than remaining profit maximisers, so that codetermination might arise as the endogenous market outcome in a Cournot duopoly (Kraft, 1998) or in oligopoly with a generic number of firms (Kraft, 2001). However, this result emerges as a prisoner's dilemma, i.e. players have an incentive to coordinate to play profit maximisation, but no one has a unilateral incentive to deviate from codetermination. The present research examined the alternative mode of competition to the Cournot setting and developed a tractable two-stage non-cooperative duopoly game with complete information describing the behaviour of price-setting firms that must choose to be profit maximisers or bargainers under codetermination *in a network industry* to account for the striking expansion of networking products in recent years. In sharp contrast with the established literature, it showed that codetermination can never emerge as a Nash equilibrium in non-network price-setting markets, whereas becoming the sub-game perfect Nash equilibrium when there are network externalities. This equilibrium can be the Pareto efficient outcome of the game (deadlock), so that the dominant strategy is also the mutually most beneficial. Therefore, codetermination in price-setting industries producing network goods could be supported by market forces (voluntary codetermination) and constitutes a Pareto-superior institution. Moreover, we showed that an endogenous level of the bargaining power maximising firm's profits does also exist.

Though we are aware that our results are theoretical by speculating about the feasibility of a labour market institution such as codetermination, and there exists evidence that codetermination is quite absent in countries where there are no specific laws, the article showed that firms have an incentive to voluntarily choose to become codetermined when prices are strategic substitutes or strategic complements and then aimed at giving elements to firms and policy makers for targeting voluntary or mandatory codetermination for strategic competitive industries. For instance, if one thinks about the impact of broadband infrastructure investments on employment and output, Katz et al. (2010) found that they will generate substantial increases in employment in Germany, especially due to the additional job creation triggered by network externalities of mobile phones and related services. The present work suggested that this networking industries may benefit from mandatory codetermination regulations by locating their own plants in regions where codetermination is subject to ad hoc legislation depending, for instance, on the number of employees (German Codetermination Act of 1976), or they may organise a voluntary agreement with unions to be codetermined on their own irrespective of the number of employees.

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Appendix. Heterogenous (exogenous) codetermination

The main text has concentrated on a network-codetermination game with price-setting firms in which the choice of whether bargaining or not under codetermination was assumed to be endogenous to the modelling setting. In a context with exogenous union-firm bargaining power (i.e., β was not subject to economic decisions or it did not depend on other economic variables) and homogeneous unions behaving symmetrically with a uniform effort, results showed that codetermination may emerge as the market outcome of a voluntary agreement between the firm and its own union bargaining unit (Section 3). This result was confirmed under endogenous codetermination, where firms chose to bargain with unions only whether a profit-maximising bargaining strength existed (Section 4). However, to partial completion of the analysis carried out so far and describing real-life cases adequately, it would be convenient to briefly present the case of heterogeneous unions (i.e., unions with different degrees of bargaining effort) that behave asymmetrically in the Nash bargaining. This is because in actual economies there may exist unions with distinct attitudes towards, e.g., the effects of investments and demand conditions on the output market or with different abilities to bargain with firms. In order to capture this feature in a model with exogenous bargaining strength, we assume that firms do not know the union's attitude at the time of bargaining and do not have the right to choose the composition of the board of representatives, as in Section 3. From a modelling perspective, the assumption of heterogeneous unions implies that $N_i = \Pi_i^{\beta_i} Z_i^{1-\beta_i}$, as in Section 4. By following the procedure used in Section 3, the payoff matrix is summarised in Table 14. Results and policy implications can be ascertained by looking at Panels (a)-(d) of Figure 3 that contrast the equilibrium outcomes of the game in the parameter space (β_1, β_2) for different (increasing) values of the strength of the network effect and a given value of the degree of product differentiation (note that the figure apply either to the case of product substitutability or product complementarity). As expected, in the absence of network effects $(n = 0)$ the unique SPNE of the game is (PM,PM). As far as the network effect increases, (B,B) emerges as the unique SPNE for a wider range of parameter values. When union-1 and union-2 bargaining efforts are sufficiently different, only the firm whose union bargaining unit undertakes a relatively small bargaining power choose the be codetermined, otherwise the firm does not want to engage in a bargaining as the union would be too much aggressive. In that case, only one firm may voluntarily agree with its union bargaining unit to contract a codetermination rule or locate its plants in a region with mandatory codetermination. The model boils down to the one of Section 3 when $\beta_1 = \beta_2 = \beta$ (the points along the main diagonal, not drawn, in the panels of Figure 3). It is interesting to note that the results of the model with homogeneous (exogenous) codetermination hold also under heterogeneous codetermination when the degree of heterogeneity in the bargaining strength is not too large. The policy implications are like those discussed in the main text.

Firm 2	PM	B

Firm 1		
PM	$\dfrac{(1-w)^2(1-d)}{(1+d)(2-n-d)^2}, \dfrac{(1-w)^2(1-d)}{(1+d)(2-n-d)^2}$	$\dfrac{(1-w)^2(1-d)[1-n+\beta_2(1+d)]^2}{(1+d)[(1-n)(2-n)+\beta_2(2-n-d^2)]^2}, \dfrac{(1-w)^2\beta_2(1-d)(2-n+d)^2}{(1+d)[(1-n)(2-n)+\beta_2(2-n-d^2)]^2}$
B	$\dfrac{(1-w)^2\beta_1(1-d)(2-n+d)^2}{(1+d)[(1-n)(2-n)+\beta_1(2-n-d^2)]^2}, \dfrac{(1-w)^2(1-d)[1-n+\beta_1(1+d)]^2}{(1+d)[(1-n)(2-n)+\beta_1(2-n-d^2)]^2}$	$\dfrac{(1-w)^2\beta_1(1-d)[1-n+\beta_2(1+d)]^2}{(1+d)[(1-n)(1-n+\beta_1+\beta_2)^2+\beta_1\beta_2(1-d^2)]^2}, \dfrac{(1-w)^2\beta_2(1-d)[1-n+\beta_1(1+d)]^2}{(1+d)[(1-n)(1-n+\beta_1+\beta_2)^2+\beta_1\beta_2(1-d^2)]^2}$

Table 14. Exogenous codetermination with heterogenous unions. Equilibrium values of profits under B and PM (payoff matrix).

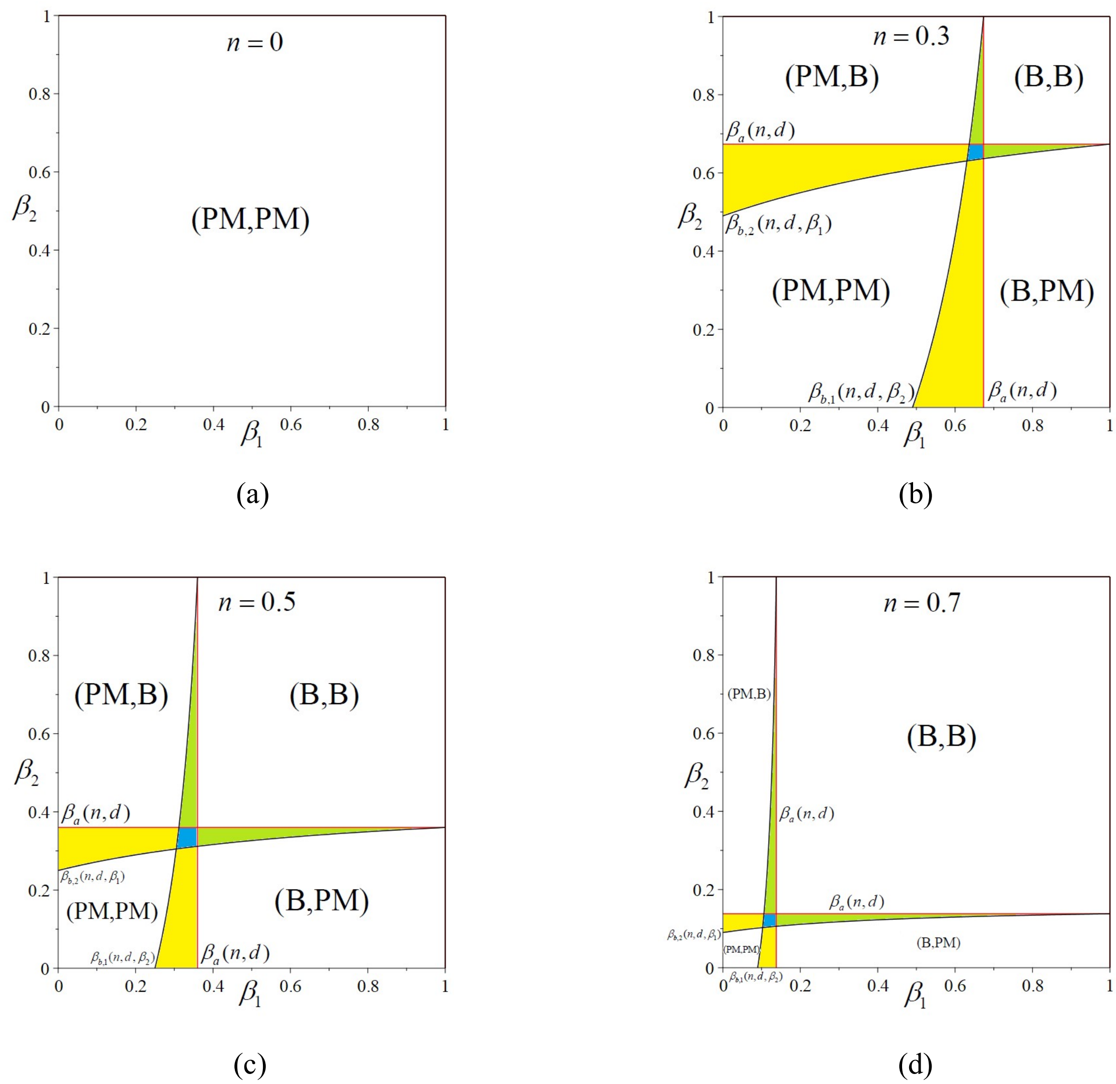

Figure 3. Codetermination and network externalities in a price-setting duopoly with heterogenous bargaining effort. Nash equilibrium outcomes in (β_1, β_2) plane for different values of n in the case of product substitutability ($d = 0.5$) and complementarity ($d = -0.5$). The red (resp. black) solid line represents the threshold value $\beta_a(n,d) := \beta_{a,1}(n,d) = \beta_{a,2}(n,d)$ (resp. $\beta_{b,1}(n,d,\beta_2)$ and $\beta_{b,2}(n,d,\beta_1)$) related to the profit differential $\Delta_a := \Delta_{a,1} = \Delta_{a,2} = 0$ (resp. $\Delta_{b,1} = 0$ and $\Delta_{b,2} = 0$). The second subscript refers to the firm. Panel (a): $n = 0$. Panel (b): $n = 0.3$. Panel (c): $n = 0.5$. Panel (d): $n = 0.7$. The yellow (resp. green) [resp. light blue] region represents

the couples (β_1, β_2) such that the unique SPNE of the game is (PM,PM) (resp. (B,B)) [resp. there exist two pure-strategy Nash equilibria (PM,PM) and (B,B)].

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