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Complementary inputs, outsourcing and vertical integration: Price versus quantity competition

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Abstract

We compare the effects of price and quantity competition in an industry with complementary inputs, outsourcing and a vertically integrated firm where vertical integration occurs between a final goods producer and a subset of input suppliers. The profit of the integrated firm and the industry profit are higher under Bertrand competition, the profit of the non-integrated firm is higher under Bertrand competition for high product differentiation, and consumer surplus and welfare are higher under Bertrand competition for low product differentiation. Further, no market foreclosure can be the preferred choice of the vertically integrated firm for any degree of product differentiation.

KEYWORDS
Bertrand, complementary inputs, Cournot, foreclosure, vertical integration

JEL CLASSIFICATION
D21, D43, L13

1 | INTRODUCTION

There is a vast literature following the seminal paper by Singh and Vives (1984) comparing the effects of Cournot and Bertrand competition on profits, consumer surplus and welfare. One set of papers compare the effects of Cournot and Bertrand competition in the absence of strategic input price determination. These papers show how the outcomes under Cournot and Bertrand competition are affected by the market sharing rule (Ghosh Dastidar, 1997), positive primary outputs (Acharyya & Marjit, 1998; Zanchettin, 2006), innovation (Bester & Petrakis, 1993; Bonanno & Haworth, 1998; Boone, 2001; Delbono & Denicolò, 1990; Mukherjee, 2011; Qiu, 1997; Reynolds & Isaac, 1992; Symeonidis, 2003), number of firms (Häckner, 2000), endogenous market structure (Cellini et al., 2004; Mukherjee, 2005), and technology licencing (Mukherjee, 2010).

There is another set of papers considering Cournot and Bertrand competition in the presence of strategic input price determination. These papers show the implications of the bargaining power of labour unions (López & Naylor, 2004), endogenous choice of the strategic variables (López, 2007) and cost asymmetry among the final goods producers (Mukherjee et al., 2012). Although these papers consider vertical relationships between the input suppliers and the final goods producers, they consider non-cooperation between the input suppliers and the final goods producers, thus ignoring the effects of vertical integration. Arya et al. (2008) fills this gap by considering vertically integrated and non-integrated firms.

Arya et al. (2008) consider a duopoly model with a vertically integrated firm that sells a critical input to the competitor and show that the standard conclusions about the effects of product market competition are reversed—Bertrand competition creates higher industry profit, lower consumer surplus and lower welfare compared to Cournot competition. They captured an important aspect of the real world, viz., outsourcing key inputs to vertically integrated competitors. As they mentioned, outsourcing key inputs to the vertically integrated retail competitors can be found in the telecommunication, soft drink, cereal, and gasoline industries. However, they considered that the production of the final goods requires a single critical input, which may not be the case in many situations.

It is often found that firms need *complementary inputs* and vertical integration may involve only a subset of input suppliers. For example, Chongvilaivan et al. (2013) note that the final goods producers, such as manufacturers of automotive and electronics, use complementary inputs like workers and parts and components, and vertical integration involves a subset of input suppliers. Manufacturers in the high-tech industry often need to buy patents from the patent holders for using their technologies. For example, smart phone companies, pharmaceutical companies need to buy patents from the patent holders (see, e.g., Osipchuk, 2018; Trappey et al., 2016).

The automotive industry has undergone a dramatic and rapid transformation in recent years. The large global producers of the sector, such as Volkswagen AG, General Motors Co. (GM), Ford Motor Co. and Toyota Motor Corporation, have shifted their production from traditional fuel-engine vehicles to electric vehicles (EVs).[1] High competition among EV makers forces them to step towards integration in the supply chains. In this way, the market players seek to guarantee in-house battery production, lower the risk of supply shortages, reduce manufacturing costs and increase efficiency (IEA, 2022, 2023). For instance, Chinese EV giant BYD Co. Ltd.

[1] https://www.ft.com/content/fb4d1d64-5d90-4e27-b77f-6e221bc02696.

(Build Your Dreams) maintains a vertical integration strategy for auto manufacturing and controls all components of EVs, such as batteries and semiconductors (Quan et al., 2018; Rong et al., 2017). BYD has also supplied its battery cells to other original equipment manufacturers (OEMs), such as Stellantis and Daimler.[2,3] The partnership between US automaker General Motors and LG Chem, a South Korean battery manufacturer, is driven by the same reasons. LG Chem has mainly supplied critical battery materials (such as processed nickel and lithium) and battery cells to GM based on the long-term supply agreement.[4] However, other OEMs such as Volkswagen, Daimler, Ford and Stellantis also outsourced battery cells through GM's long-term partner LG Chem to bolster their competitiveness in the EV industry.[5]

This change in the automotive industry also raises questions about the relationship with labour unions. For example, GM has a long history of negotiating with labour unions, including the United Auto Workers union. Daimler negotiates with the labour union IG Metall.[6] Similarly, BYD Coach & Bus could be the first battery electric bus manufacturer in the US EV market to partner with unions such as the International Association of Sheet Metal, Air, Rail, and Transportation Workers Union (SMART).[7]

There are other evidences also. In light metal manufacturing, Alcoa Inc. sources in-house cast sticks for downstream investment casting, supplies independent investment casters, and has a workforce network that includes members of United Steel Workers and members of Unite.[8] It is also found that cereal and soft-drink manufacturers supply critical inputs to their retail competitors and also deal with labour unions.

Hence, vertical integrations in the above-mentioned cases involve the final goods producers and a subset of input suppliers, which is not captured by Arya et al. (2008). This phenomenon motivates us to extend the line of research of Arya et al. (2008) with complementary inputs, outsourcing and vertical integration where vertical integration occurs between a final goods producer and a subset of input suppliers. We consider a model like Arya et al. (2008) with the exception that the final goods producers require two perfectly complementary inputs—an intermediate good and labour—and the vertically integrated firm produces the intermediate good for its own use and sells it to the rival non-integrated final goods producer.[9] However, there is no vertical integration between the firms and the labour unions supplying workers.

[2] https://www.ft.com/content/d407772c-4a76-4e59-9bb0-998b3f22383b; https://www.electrive.com/2021/07/13/stellantis-to-source-batteries-from-svolt/.

[3] https://news.metal.com/newscontent/101268191/byd-will-supply-blade-batteries-to-daimler-parent-company-of-mercedes-benz-tesla-purchases-low-carbon-nickel.

[4] https://investor.gm.com/news-releases/news-release-details/lg-chem-and-general-motors-reach-agreement-long-term-supply/#:~:text=Through%20the%20long%2Dterm%20supply,million%20units%20of%20EV%20production.

[5] https://www.reuters.com/article/us-lg-chem-daimler-idUSKBN0MQ05020150330. Also, see Harrison and Ludwig (2021) for a discussion on the battery supply chain in electric vehicle market. https://www.automotivelogistics.media/battery-supply-chain/electric-vehicle-battery-supply-chain-analysis-2021-how-lithium-ion-battery-demand-and-production-are-reshaping-the-automotive-industry/41924.article.

[6] https://www.reuters.com/article/us-germany-wages-idINKBN1F72GJ.

[7] https://smart-union.org/tag/byd/.

[8] Text for vertically integrated input suppliers is available from http://eur-lex.europa.eu/search.html?qid=1467417618606&text=Case%20No%20COMP/M.7342%20%20ALCOA/%20FIRTH%20RIXSON&scope=EURLEX&type=quick&lang=en.

[9] Reisinger and Tarantino (2019) consider an industry with vertical integrated firms and complementary patent holders. However, their focus is different from ours. They examine the anticompetitive effects of cooperation among the complementary patent holders in the presence of vertical integration among the patent owners and the final good producers.

Considering decentralised or firm-specific labour unions, we show that the profit of the integrated firm and the total profits of the firms are higher under Bertrand competition, the profit of the non-integrated firm is higher under Bertrand competition for high product differentiation, and consumer surplus and social welfare are higher under Bertrand competition for low product differentiation. We show in Appendix F that similar qualitative results hold under an industry-wide or a centralised labour union. Thus, our results complement and contrast with the standard conclusion and that of with Arya et al. (2008).

Unlike the standard conclusion, we show that profits can be higher, and consumer surplus and welfare can be lower under Bertrand competition. However, in contrast to Arya et al. (2008), we show that the profit of the non-integrated firm, consumer surplus and welfare may not be higher under Bertrand competition for any degree of product differentiation.

Like the other papers mentioned above, showing profit and welfare reversals under Bertrand-Cournot competition, these results suggest that the firms may not be worse off under more intense competition, and the consumers and the society may not be worse off under less intense competition. However, in contrast to those papers we show the implications of complementary input suppliers with significant bargaining power. As shown, in the presence of complementary input suppliers with significant market power, the degree of product-substitutability also plays an important role for these implications.

The reasons for our results are as follows. The integrated firm faces the same costs of production for the intermediate goods under Cournot and Bertrand competition, but it faces lower wages under Bertrand competition, implying that its marginal cost of production (which is the sum of intermediate goods costs and wages) is lower under Bertrand competition. The non-integrated firm faces higher wages, lower intermediate goods prices and higher marginal costs under Bertrand competition for high product differentiation. As in Arya et al. (2008), the integrated firm's incentive for softening competition through intermediate goods price is higher under Bertrand competition. However, in our analysis, the presence of the labour union allows the integrated firm to achieve this objective only for high product differentiation since higher intermediate goods prices induce the labour union to lower its wages in the non-integrated firm.

Hence, on one hand, lower marginal cost of the integrated firm under Bertrand competition helps to increase the integrated firm's profit and to reduce the non-integrated firm's profit under Bertrand competition. On the other hand, higher marginal cost of the non-integrated firm under Bertrand competition for high product differentiation tends to increase both firms' profits under Bertrand competition for high product differentiation by softening competition. Both the effects create higher profit for the integrated firm under Bertrand competition for high product differentiation. If the products are close substitutes, the marginal costs of both firms are lower under Bertrand competition compared to Cournot competition, which help to reduce the price and increase the output of the integrated firm under Bertrand competition compared to Cournot competition, and the output gain outweighs the price loss to increase the integrated firm's profit under Bertrand competition.[10] For the non-integrated firm, the competition softening effect helps to increase its profit under Bertrand competition for high product differentiation.

[10]This effect can be related to Zanchettin (2006), which didn't consider a vertical structure and considered the same marginal costs of the firms under Bertrand and Cournot competition. In our analysis, the marginal costs of the firms are different under Bertrand and Cournot competition due to the presence of the vertical structure.

The higher profits of the integrated and non-integrated firms under Bertrand competition for high product differentiation make the industry profit higher under Bertrand competition for high product differentiation. For low product differentiation, the higher profit of the integrated firm under Bertrand competition helps to create higher industry profit under Bertrand competition. Thus, the industry profit is higher under Bertrand competition.

The effects mentioned above are similar to Arya et al. (2008), with the exception that the competition softening effect due to a higher marginal cost of the non-integrated firm under Bertrand competition occurs only for high product differentiation. This happens due to the presence of complementary inputs. Since the integrated firm did not need to care about other input prices in Arya et al. (2008), the integrated firm could charge higher intermediate goods prices under Bertrand competition always. However, in our paper, a higher (lower) intermediate goods price encourages the labour union to reduce (increase) the wage for the non-integrated firm. Hence, the intermediate goods prices charged by the integrated firm and the wages charged by the labour union to the non-integrated firm goes in the opposite direction. On balance, this trade-off makes the sum of the intermediate goods prices and the wages for the non-integrated firm higher under Bertrand competition only for high product differentiation since significant competition under close substitutes induces the labour union to reduce wages significantly, thus creating a difference from Arya et al. (2008).

The reasons for the effects on consumer surplus and welfare are also attributed to the effects on the marginal costs of the firms. The integrated firm's lower marginal cost under Bertrand competition and the non-integrated firm's lower marginal cost under Bertrand competition for low product differentiation help to create higher consumer surplus and welfare under Bertrand competition for low product differentiation. However, the higher marginal cost of the non-integrated firm under Bertrand competition for high product differentiation is responsible for softening competition and creating lower consumer surplus and welfare under Bertrand competition for high product differentiation. Since the competition softening effect occurs in our paper only for high product differentiation, unlike Arya et al. (2008), lower consumer surplus and lower welfare under Bertrand competition occurs in our paper only for high product differentiation.

An important concern for the antitrust authorities on vertical integration is vertical closure. It is generally believed that vertical integration between an input supplier and a final goods producer discourages the integrated firm to supply the input to other non-integrated final goods producers in the absence of alternative sources of inputs (see, e.g., Hart & Tirole, 1990; Rey & Tirole, 2007; Salinger, 1988; Zanchettin & Mukherjee, 2017). Arya et al. (2008), Zanchettin and Mukherjee (2017) and Moresi and Schwartz (2017) show that vertical foreclosure does not occur if the final goods are differentiated. Differentiated final goods attract new consumers and make no vertical foreclosure as the preferred option. Hence, those papers suggest that vertical foreclosure as a reason to challenge vertical integration decision is not relevant if the products of the integrated and non-integrated final goods producers are differentiated.

We show in this paper that vertical foreclosure does not occur even if the products of the integrated and the non-integrated firms are perfect substitutes and there is no firm-asymmetry, but the firms use complementary inputs and integration occurs between a final goods producer and a subset of input suppliers. The reason for our result is as follows. On the one hand, foreclosure reduces competition in the product market, but, on the other hand, the labour union, which is the non-integrated input supplier, uses its prices to extract gains from vertical foreclosure. Since the integrated firm can manipulate the intensity of product-market competition through its input price, it prefers no foreclosure to reduce rent extraction by the non-integrated input supplier. Hence, no vertical foreclosure in our paper is due to rent extraction motive of the non-integrated complementary input supplier.

Thus, we show that vertical foreclosure as a reason to challenge the vertical integration decision is not relevant even for homogeneous products if there are complementary inputs and the integrated final goods producers integrate with a subset of input suppliers. As mentioned above, this can be found in many industries, such as the automotive, electronics, cereal and soft-drink industries. The manufacturers in those industries use complementary inputs like workers and critical inputs, and some of the manufactures in those industries produce the critical inputs like vertical integrated firms and supply those inputs to their product-market competitors.

Hence, the contributions of our paper are two-fold. First, it shows the effects of product-market competition on the profits, consumer surplus and welfare in the presence of complementary inputs and vertical integration between a final goods producer and a subset of input suppliers. Second, it shows the implications of complementary inputs and vertical integration between a final goods producer and a subset of input suppliers on vertical foreclosure, which is a concern for the antitrust authorities.[11]

The remainder of the paper is organised as follows. Section 2 describes the model. Section 3 shows the results under Cournot competition. Section 4 shows the results under Bertrand competition. Section 5 compares the effects of Cournot and Bertrand competition on the profits, consumer surplus and social welfare. Section 6 discusses the implications of positive bargaining power of firms. Section 7 concludes. We show the implications of a centralised labour union in Appendix F.

2 | THE MODEL

Assume that there is a vertically integrated firm, Firm I, which produces an intermediate good and uses it to produce a final good. Firm I also needs workers to produce the final goods. There is another non-integrated final goods producer, Firm NI, which cannot produce the intermediate good but can produce the final good by employing workers and sourcing the intermediate good from Firm I. Consider for simplicity that one unit of the final good requires one unit of intermediate good and one worker.

Häckner (2000) showed that the results of Singh and Vives (1984) may not hold if there are more than two firms competing in the market. To eliminate the effects shown by Häckner (2000), we consider duopoly in the final goods market.

Assume that the marginal cost of production for the intermediate good is $c(>0)$. Hence, Firm I can procure the intermediate good at c. However, Firm NI has access to the intermediate good through Firm I by paying a price, α_{NI}, which is determined by Firm I.

We consider that workers are unionised and the firms hire workers from firm-specific or decentralised labour unions. We will show in Appendix F the implications of an industry-wide or a centralised labour union, where the firms hire workers from an industry-wide or a centralised labour union.[12] We assume that the reservation (or competitive) wage for each worker

[11]Our structure is also related to Chongvilaivan et al. (2013), which consider vertical relationship with complementary inputs. However, unlike us, they didn't consider the implications of product-market competition and the effects on vertical foreclosure.

[12]See, for example, Flanagan (1999) and OECD (2004, 2018) for different degree of wage centralisation across countries.

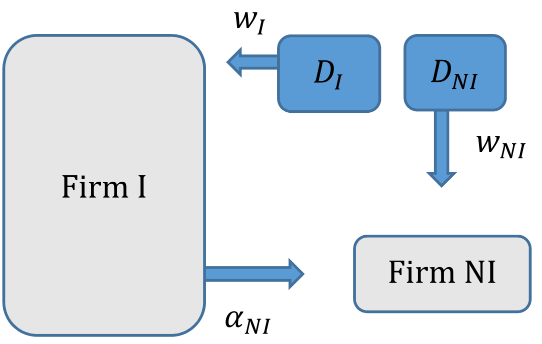

FIGURE 1 Decentralised unions.

is r. Figure 1 below depicts the structure of the industry. The unions D_I and D_{NI} charge wages w_I and w_{NI} to Firms I and NI, respectively.

We assume that a representative consumer's utility function is $U = a(q_i + q_j) - \beta \left[\left(q_i^2 + q_j^2\right) + 2\theta q_i q_j\right]/2$ that yields the inverse market demand function for the final goods as

$$P_i = a - \beta(q_i + \theta q_j) \tag{1}$$

where P_i and q_i show Firm i's price and output respectively, q_j shows Firm j's output, $i = I, NI; i \neq j$, and $\theta \in [0,1]$ represents the degree of product differentiation. The products are perfect substitutes if $\theta = 1$, while the products are isolated for $\theta = 0$.

We consider the following game. At stage 1, Firm I decides whether to sell the intermediate good to Firm NI. Vertical foreclosure occurs (does not occur) if Firm I does not sell (sells) the intermediate good to Firm NI. If there is no foreclosure, at stage 2, Firm I charges the input price, α_{NI}, to Firm NI and the decentralised unions, D_I and D_{NI}, charge wages w_I and w_{NI} to Firms I and NI respectively.[13] However, if there is foreclosure, Firm I does not sell the intermediate good to Firm NI and the labour union D_I charges wage to Firm I only. At stage 3, production takes place. If there is no foreclosure, Firms I and NI compete like Cournot duopolists (as considered in Section 3) or like Bertrand duopolists (as considered in Section 4) and the profits are realised. If there is foreclosure, Firm I produces like a monopolist and the profits are realised. We solve the game through backward induction.

If there is foreclosure, there is no competition in the product market and Firm I produces like a monopolist. We first consider the case of foreclosure before considering the case of no foreclosure.

[13]Many papers considered in different contexts that labour unions determined wages (see, Dowrick, 1989, Naylor, 1998, Straume, 2002; Lommerud et al., 2003; Haucap & Wey, 2004; Mukherjee, 2008; Mukherjee & Pennings, 2011; Mukherjee et al., 2012, to name a few). As Dowrick (1989) mentioned 'The "monopoly union" is treated as a limiting case of the wage-bargaining union'. It is often used as a modelling strategy to give the unions maximum power in wage determination so that the unions' implications are shown in the easiest way. Instead of unions supplying workers, our model will be applicable also for patent holders charging royalties to Firms I and NI for patents. In that case, it may be more natural to consider that the patent holders have full bargaining power to set the royalty rates. See, for example, Shapiro (2001), Lerner and Tirole (2004) and Choi (2010) for patent holders determining the royalty rates.

2.1 | Vertical foreclosure

In case of vertical foreclosure, Firm I does not supply the intermediate good to Firm NI. In this situation, Firm I maximises the following expression to determine its output.

$$\pi_I^f = (a - \beta q_I - c - w_I)q_I.$$

The equilibrium output of Firm I can be found as $q_I^f = \frac{a-c-w_I}{2\beta}$.

The labour union determines the wage rate by maximising its utility function, $(w_I - r)L_I$, where $q_I^f = \frac{a-c-w_I}{2\beta} = L_I$.[14] Straightforward calculation gives $\widehat{w}_I^f = \frac{a-c+r}{2}$. Given the equilibrium wage, the equilibrium output of Firm I is $\widehat{q}_I^f = \frac{a-c-r}{4\beta}$. The equilibrium output is positive if $a > c + r$, that is, if the demand intercept is higher than the sum of the marginal cost of production for the intermediated goods and the reservation wage, which we assume to hold. If this condition is not satisfied, production is unprofitable even if the firm gets the intermediate goods at its marginal cost and the workers at the reservation wage.

The equilibrium profit of Firm I under foreclosure is

$$\widehat{\pi}_I^f = \frac{(a-c-r)^2}{16\beta}. \quad (2)$$

The equilibrium consumer surplus is

$$CS^f = \frac{(a-c-r)^2}{32\beta}. \quad (3)$$

The equilibrium social welfare (W), which is the sum of the industry profit, the union utility and consumer surplus, is

$$W^f = \frac{7(a-c-r)^2}{32\beta}. \quad (4)$$

3 | COURNOT COMPETITION

Now we consider the case of no foreclosure and Cournot competition in the final goods market. In this situation, Firm I supplies the intermediate good to Firm NI and maximises the following expression to determine its output, q_I:

$$\pi_I^{c,d,nf} = (a - \beta(q_I + \theta q_{NI}) - c - w_I)q_I + (\alpha_{NI} - c)q_{NI}.$$

[14] If Firm I does not supply the inputs to Firm NI, only Firm I produces the product. In this situation, there is no issue of decentralised and centralised unions.

Firm NI maximises the following expression to determine its output, q_{NI}:

$$\pi_{NI}^{c,d,nf} = (a - \beta(\theta q_I + q_{NI}) - \alpha_{NI} - w_{NI})q_{NI}.$$

The equilibrium outputs of Firms I and NI are respectively $q_I^{c,d,nf} = \frac{2(a-c-w_I)-\theta(a-\alpha_{NI}-w_{NI})}{\beta(4-\theta^2)}$ and $q_{NI}^{c,d,nf} = \frac{2(a-\alpha_{NI}-w_{NI})-\theta(a-c-w_I)}{\beta(4-\theta^2)}$.

The equilibrium wages under decentralised labour unions are determined by maximising $U_I^d = (w_I - r)q_I^{c,d,nf}$ and $U_{NI}^d = (w_{NI} - r)q_{NI}^{c,d,nf}$ with respect to w_I and w_{NI} respectively. The equilibrium intermediate good price, α_{NI}, is determined by maximising $\pi_I^{c,d,nf} = (a - \beta(q_I + \theta q_{NI}) - c - w_I)q_I^{c,d,nf} + (\alpha_{NI} - c)q_{NI}^{c,d,nf}$, subject to the equilibrium outputs shown above. The intermediate goods price and wages are determined simultaneously.

The equilibrium intermediate goods price and the wages under decentralised unions are

$$\widehat{\alpha}_{NI}^{c,d,nf} = \frac{1}{2}(a + c - r) - \frac{(a-c-r)(8-\theta(4+\theta))}{48 - 18\theta^2 + \theta^4}.$$

$$\widehat{w}_I^{c,d,nf} = \frac{(a-c)(2-\theta)^2(2+\theta)(3+\theta) + r\left(4\theta - \theta^2(8+\theta) + 24\right)}{48 - 18\theta^2 + \theta^4},$$

$$\widehat{w}_{NI}^{c,d,nf} = \frac{(a-c)(2-\theta)(2+\theta)(8-\theta(4+\theta)) + r(64+\theta(16-\theta(24+\theta(4-\theta))))}{2\left(48 - 18\theta^2 + \theta^4\right)}.$$

Given the intermediate goods price and wages, the equilibrium outputs of Firms I and NI are $\widehat{q}_I^{c,d,nf} = \frac{2(a-c-r)(2-\theta)(3+\theta)}{\beta\left(48-18\theta^2+\theta^4\right)}$ and $\widehat{q}_{NI}^{c,d,nf} = \frac{(a-c-r)(8-\theta(4+\theta))}{\beta\left(48-18\theta^2+\theta^4\right)}$, and the corresponding profits are

$$\widehat{\pi}_I^{c,d,nf} = \frac{(a-c-r)^2(2-\theta)(272+\theta(56-\theta(4+\theta)(28-\theta(2+\theta))))}{2\beta\left(48 - 18\theta^2 + \theta^4\right)^2}, \tag{5}$$

$$\widehat{\pi}_{NI}^{c,d,nf} = \frac{(a-c-r)^2(8-\theta(4+\theta))^2}{\beta\left(48 - 18\theta^2 + \theta^4\right)^2}. \tag{6}$$

The equilibrium consumer surplus is

$$CS^{c,d,nf} = \frac{(a-c-r)^2(208+\theta(80-\theta(172+\theta(24-\theta(25+4\theta)))))}{2\beta\left(48 - 18\theta^2 + \theta^4\right)^2}. \tag{7}$$

The equilibrium welfare is

$$W^{c,d,nf} = \frac{(a-c-r)^2(1712-\theta(656+\theta(836-\theta(240+\theta(123-2\theta(8+3\theta))))))}{2\beta\left(48 - 18\theta^2 + \theta^4\right)^2}. \tag{8}$$

Proposition 1. *Under Cournot competition, if the integrated and non-integrated firms hire workers from decentralised labour unions, the integrated firm supplies the intermediate good to the non-integrated firm for any degree of production differentiation (i.e., for any $\theta \in [0,1]$), implying that the integrated firm prefers no vertical foreclosure.*

Proof: See Appendix A. ■

Proposition 1 sheds new light on vertical foreclosure. It shows that if there are complementary inputs and vertical integration involves only a subset of input suppliers, vertical foreclosure is not a concern.

Arya et al. (2008), Zanchettin and Mukherjee (2017) and Moresi and Schwartz (2017) show that vertical foreclosure does not occur if the final goods are differentiated. On one hand, no vertical foreclosure increases competition in the product market but on the other hand, it helps to attract more consumers when the final goods are differentiated. Since the intermediate goods price helps to control the intensity of competition in the product market, the firms prefer no vertical foreclosure when the final goods are differentiated, since product differentiation attracts more consumers.

We show that vertical foreclosure is not preferable even if the products are homogeneous. In our paper, no vertical foreclosure helps to reduce wages in the integrated firm compared to vertical foreclosure (i.e., $\widehat{w}_I^{c,d,nf} < \widehat{w}_I^f$) and therefore, helps to extract rent from the labour union by increasing competition in the product market. This benefit from rent extraction from the labour union makes no vertical foreclosure beneficial even if the final goods are homogeneous. If the final goods are differentiated, no vertical foreclosure in our paper is beneficial since it helps to extract rent from the labour union and attracts more consumers.

4 | BERTRAND COMPETITION

Now consider no foreclosure under Bertrand competition. The inverse market demand function for the final goods is given by (1), and the corresponding direct demand function is

$$q_i = \frac{(a - P_i) - \theta(a - P_j)}{\beta(1 - \theta^2)}. \tag{9}$$

Under Bertrand competition, we consider $\theta \in [0,1)$ to avoid the well-known Bertrand-paradox.

Under no foreclosure, Firm I sells the intermediate good to Firm NI and maximises the following expression to determine its price, P_I:

$$\underset{P_I}{Max}\, \pi_I^{b,d,nf} = (P_I - c - w_I)q_I + (\alpha_{NI} - c)q_{NI}. \tag{10}$$

Firm NI maximises the following expression to determine its price, P_{NI}:

$$\underset{P_{NI}}{\text{Max}}\, \pi_{NI}^{b,d,nf} = (P_{NI} - \alpha_{NI} - w_{NI})q_{NI}. \tag{11}$$

We get the equilibrium prices as

$$P_I^{b,d,nf} = \frac{2(a+c+w_I) - (a+2c-3\alpha_{NI} - w_{NI})\theta - a\theta^2}{4-\theta^2}, \tag{12}$$

$$P_{NI}^{b,d,nf} = \frac{2(a+\alpha_{NI}+w_{NI}) - (a-c-w_I)\theta - (a+c-\alpha_{NI})\theta^2}{4-\theta^2}. \tag{13}$$

The equilibrium outputs are

$$q_I^{b,d,nf} = \frac{a\left(2-\theta-\theta^2\right) - 2(c+w_I) + \theta\left(w_{NI} + w_I\theta + c\left(2+\theta-\theta^2\right) + \alpha_{NI}\left(-1+\theta^2\right)\right)}{\beta\left(4-5\theta^2+\theta^4\right)},$$

$$q_{NI}^{b,d,nf} = \frac{a\left(2-\theta-\theta^2\right) - 2(w_{NI}+\alpha_{NI}) + \theta(c+w_I - c\theta + (w_{NI}+2\alpha_{NI})\theta)}{\beta\left(4-5\theta^2+\theta^4\right)}.$$

The unions and Firm I determine the wages and the intermediate goods price simultaneously. The wages under decentralised unions are determined by maximising $(w_i - r)q_i^{b,d,nf}$, $i \in \{I, NI\}$, and the price for the intermediate goods is determined by maximising $(P_I - c - w_I)q_I^{b,d,nf} + (\alpha_{NI} - c)q_{NI}^{b,d,nf}$.

We get the equilibrium intermediate goods price and the wages as

$$\widehat{\alpha}_{NI}^{b,d,nf} = \frac{\begin{pmatrix} (a-c)(2+\theta)(4-(2-\theta)\theta)\left(2-\theta^2\right)(4+\theta(1-2\theta)) \\ +c\left(128-\theta\left(16+88\theta+\theta^3(18-\theta(8+\theta(17-2\theta(1+\theta))))\right)\right)\end{pmatrix}}{2\left(96-76\theta^2+8\theta^6+\theta^8\right)}.$$

$$\widehat{w}_I^{b,d,nf} = \frac{\begin{matrix} 48r + (a-c)(2-\theta)(1-\theta)(2+\theta)^2\left(6-\theta^2+\theta^3-\theta^4\right) \\ + r\theta(2-\theta)(2+\theta)(6-\theta(8+\theta(3+2\theta)))\end{matrix}}{96-76\theta^2+8\theta^6-\theta^8},$$

$$\widehat{w}_{NI}^{b,d,nf} = \frac{\begin{matrix} (a-c)(2-\theta)(1-\theta)(2+\theta)\left(2+\theta^2\right)(8+(1-\theta)\theta(4+\theta)) \\ + r\left(2-\theta^2\right)(64+\theta(16-\theta(24-\theta(4-\theta(5+\theta(2-\theta))))))\end{matrix}}{2\left(96-76\theta^2+8\theta^6-\theta^8\right)}.$$

Given the equilibrium intermediate goods price and wages, the equilibrium outputs are $\widehat{q}_I^{b,d,nf} = \frac{(a-c-r)(2+\theta)\left(2-\theta^2\right)\left(6-\theta^2+\theta^3-\theta^4\right)}{\beta(1+\theta)\left(96-76\theta^2+8\theta^6-\theta^8\right)}$ and $\widehat{q}_{NI}^{b,d,nf} = \frac{(a-c-r)\left(2-\theta^2\right)\left(2+\theta^2\right)(8+(1-\theta)\theta(4+\theta))}{2\beta(1+\theta)\left(96-76\theta^2+8\theta^6-\theta^8\right)}$.

The equilibrium profits of Firm I and Firm NI are respectively

$$\widehat{\pi}_I^{b,d,nf} = \frac{(a-c-r)^2(2+\theta)\left(2-\theta^2\right)^2\left(\begin{array}{l}544+\theta(304-\theta(240+\theta(56+\theta(52\\ +\theta(46-\theta(24+\theta(5+3\theta)))))))\end{array}\right)}{4\beta(1+\theta)\left(96-76\theta^2+8\theta^6-\theta^8\right)^2}, \tag{14}$$

$$\widehat{\pi}_{NI}^{b,d,nf} = \frac{(a-c-r)^2(1-\theta)\left(2-\theta^2\right)^2\left(2+\theta^2\right)^2(8+(1-\theta)\theta(4+\theta))^2}{4\beta(1+\theta)\left(96-76\theta^2+8\theta^6-\theta^8\right)^2}. \tag{15}$$

The equilibrium consumer surplus and social welfare are respectively

$$CS^{b,d,nf} = \frac{(a-c-r)^2\left(2-\theta^2\right)^2\left(\begin{array}{l}832+\theta(768+\theta(80+\theta(176-\theta(124+\theta(252\\ +\theta(24+\theta(1+\theta)(16-\theta(13+4\theta))))))))\end{array}\right)}{8\beta(1+\theta)\left(96-76\theta^2+8\theta^6-\theta^8\right)^2}, \tag{16}$$

$$W^{b,d,nf} = \frac{(a-c-r)^2\left(2-\theta^2\right)\left(\begin{array}{l}13696+\theta(6144-\theta(12256+\theta(4128+\theta(984\\ +\theta(1688-\theta(2724+\theta(1332-\theta(242+\theta(2\\ +\theta(163+\theta(95-12\theta(2+\theta)))))))))))\end{array}\right)}{8\beta(1+\theta)\left(96-76\theta^2+8\theta^6-\theta^8\right)^2}. \tag{17}$$

Proposition 2. *Under Bertrand competition, if the integrated and non-integrated firms hire workers from decentralised labour unions, the integrated firm supplies the intermediate good to the non-integrated firm for any $\theta \in [0,1)$, implying that the integrated firm prefers no foreclosure.*

Proof: See Appendix B. ■

The reason for Proposition 2 is similar to Proposition 1.

5 | COMPARISON BETWEEN COURNOT AND BERTRAND

Since we focused on $\theta \in [0,1)$ under Bertrand competiton, we consider $\theta \in [0,1)$ in this section. Before comparing the profits, consumer surplus and welfare under Cournot and Bertrand competition, first compare the effects of product-market competition on the wages and the intermediate goods price.

We plot $\frac{\Delta \widehat{w}_I}{(a-c-r)}$ for different values of $\theta \in [0,1)$ in Appendix C, where $\Delta \widehat{w}_I = \widehat{w}_I^{b,d,nf} - \widehat{w}_I^{c,d,nf}$. It shows that the wage for the integrated firm is lower under Bertrand competition compared to Cournot competition for $0 < \theta < 1$.

Now consider $\frac{\Delta \widehat{w}_{NI}}{(a-c-r)} = \frac{\widehat{w}_{NI}^{b,d,nf} - \widehat{w}_{NI}^{c,d,nf}}{(a-c-r)}$, $\frac{\Delta \widehat{\alpha}_{NI}}{(a-c-r)} = \frac{\widehat{\alpha}_{NI}^{b,d,nf} - \widehat{\alpha}_{NI}^{c,d,nf}}{(a-c-r)}$ and $\frac{\Delta \widehat{MC}_{NI}}{(a-c-r)} = \frac{\left(\widehat{w}_{NI}^{b,d,nf} + \widehat{\alpha}_{NI}^{b,d,nf}\right) - \left(\widehat{w}_{NI}^{c,d,nf} + \widehat{\alpha}_{NI}^{c,d,nf}\right)}{(a-c-r)}$. See Appendix C for the expressions of $\frac{\Delta \widehat{w}_{NI}}{(a-c-r)}$, $\frac{\Delta \widehat{\alpha}_{NI}}{(a-c-r)}$ and $\frac{\Delta \widehat{MC}_{NI}}{(a-c-r)}$. We plot them for $\theta \in [0,1)$ in Figure 2.

We get the following results from the above discussion and Figure 2.

Lemma 1.

(i) The wage for the integrated firm is lower under Bertrand competition compared to Cournot competition for $\theta \in (0,1)$.
(ii) *The wage for the non-integrated firm is higher under Bertrand competition compared to Cournot competition for* $\theta < \widehat{\theta} = 0.559$ (approx.).
(iii) *The intermediate goods price faced by the non-integrated firm is higher under Bertrand competition compared to Cournot competition for* $\theta > \overline{\theta} = 0.467$ (approx.).
(iv) *The marginal cost of the non-integrated firm is higher under Bertrand competition compared to Cournot competition for* $\theta < \overline{\overline{\theta}} = 0.705$ (approx.).

Price cutting under Bertrand competition is more effective than quantity raising under Cournot competition to extract market share from the competitor. As a result, the firms face more intense competition under Bertrand competition compared to Cournot competition.

Ceteris paribus, fierce competition under Bertrand competition compared to Cournot competition tends to reduce the profit and, therefore rent extraction by the union under Bertrand competition compared to Cournot competition. As a result, the labour union to charge a lower wage to Firm I under Bertrand competition compared to Cournot competition to maintain its competitiveness and profitability under Bertrand competition.

Now consider the effects on Firm NI. As mentioned in the introduction, like Arya et al. (2008), the integrated firm is incentivised to soften competition under Bertrand competition by appropriately charging the intermediate goods price. However, as the intermediate

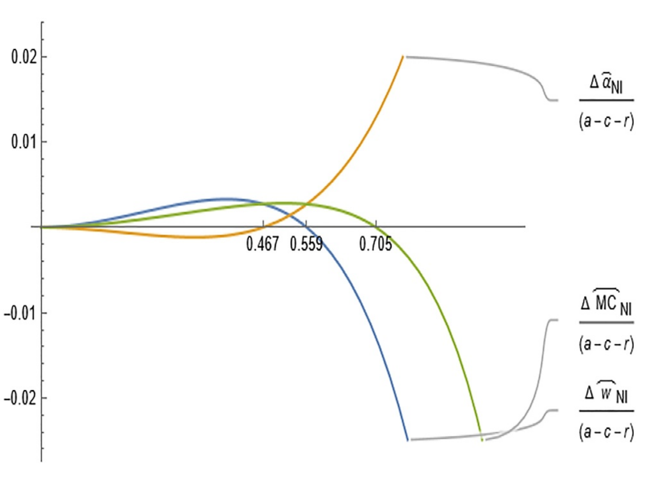

FIGURE 2 $\frac{\Delta \widehat{w}_{NI}}{(a-c-r)}$, $\frac{\Delta \widehat{\alpha}_{NI}}{(a-c-r)}$ and $\frac{\Delta \widehat{MC}_{NI}}{(a-c-r)}$ for $\theta \in [0,1)$.

goods price affects the competitiveness of the non-integrated firm by affecting the non-integrated firm's marginal cost of production (which we call as the direct effect of the intermediate goods price),[15] it also influences the non-integrated firm's marginal cost of production and profitability by affecting the wage for the non-integrated firm (which we call as the indirect effect of the intermediate goods price).[16] Firm I needs to consider the direct effect of the intermediate goods price as well as the indirect effect of the intermediate goods price through wage, since higher intermediate goods price induces the labour union to charge a lower wage to Firm NI to keep Firm NI more competitive in the product market.

If the products are close substitutes ($\theta > \widehat{\theta} = 0.559$), Firm I charges a significantly higher intermediate goods price $\left(\widehat{\alpha}_{NI}\right)$ under Bertrand competition to keep the competition from Firm NI at a low level, which induces the labour union to charge a significantly lower wage $(\widehat{w}_{NI})$ to Firm NI under Bertrand competition.

On the other hand, if the products are sufficiently differentiated ($\theta < \overline{\theta} = 0.467$), Firm I charges a lower intermediate goods price under Bertrand competition since the competition from Firm NI is not significant, which induces the labour union to charge a higher wage to Firm NI under Bertrand competition for extracting higher rent from Firm NI.

If the product differentiation is moderate ($\overline{\theta} = 0.467 < \theta < \widehat{\theta} = 0.559$), Firm I chooses the intermediate goods price to soften competition directly through intermediate goods price as well as indirectly through wage. In this situation, both the intermediate goods price and the wage for Firm NI are higher under Bertrand competition compared to Cournot competition.

Since a higher intermediate goods price reduces the wage paid by Firm NI, if the products are very close substitutes ($\theta > \overline{\overline{\theta}} = 0.705$), a higher intermediate goods price reduces the wage for Firm NI significantly under Bertrand competitoin to reduce the marginal cost of Firm NI under Bertrand competition compared to Cournot competition.

Table 1 summarises the intermediate goods price, wage and the marginal cost for Firm NI under Bertrand competition compared to Cournot competiton depending on the degree of product differentiation.

Now we compare the profits, consumer surplus and social welfare under Cournot and Bertrand competitions. Since vertical foreclosure will not occur irrespective of the type of product-market competition, the relevant expressions are given in Section 3 and 4.

Proposition 3.

(i) *Bertrand competition generates higher profit for the integrated firm compared to Cournot competition for* $\theta \in (0,1)$.
(ii) *Bertrand competition generates higher profit for the non-integrated firm compared to Cournot competition for* $\theta < \theta = 0.686$ *(approx.).*
(iii) *Bertrand competition generates higher industry profit compared to Cournot competition for* $\theta \in (0,1)$.

[15]It follows from the non-integrated firm's profit function $(a - \beta(\theta q_I + q_{NI}) - \alpha_{NI} - w_{NI})q_{NI}$ that a higher α_{NI} reduces the non-integrated firm's competitiveness by increasing the marginal cost of the non-integrated firm.

[16]We get from the first order condition of profit maximisation for the union related to the non-integrated firm that $w_{NI} = \frac{1}{4}(2a + 2r - a\theta + c\theta + \theta w_{\mathrm{I}} - 2\alpha_{NI})$, which suggest that the a higher α_{NI} reduces w_{NI}, that is, the wage rate for the non-integrated firm.

TABLE 1 Bertrand competition compared to Cournot competition; $\theta = 0.705$, $\hat{\theta} = 0.559$, $\bar{\theta} = 0.467$.

	Very close substitutes ($\theta < \theta$)	**Close substitutes $\left(\hat{\theta} < \theta < \theta\right)$**	**Moderately differentiated products $\left(\bar{\theta} < \theta < \hat{\theta}\right)$**	**Highly differentiated products $\left(\theta < \bar{\theta}\right)$**
Intermediate goods price for the non-integrated firm $(\hat{\alpha}_{NI})$	Higher	Higher	Higher	Lower
Wage for the non-integrated firm $(\hat{w}_{NI})$	Lower	Lower	Higher	Higher
Marginal cost for the non-integrated firm $\left(\widehat{MC}_{NI}\right)$	Lower	Higher	Higher	Higher

Proof: See Appendix D. ■

The reasons for these results are explained in the introduction. The lower marginal cost of Firm I under Bertrand competition and the higher marginal cost of Firm NI under Bertrand competition for high product differentiation help to create higher profit of the integrated firm under Bertrand competition for high product differentiation. If the products are close substitutes, Firm I's output gain under Bertrand competition outweighs its price loss under Bertrand competition to increase its profit under Bertrand competition.

On the other hand, the competition softening effect helps the non-integrated firm to earn higher profit under Bertrand competition for high product differentiation.

While both firms earn higher profits under Bertrand competition for high product differentiation, the higher profit of the integrated firm helps to create higher industry profit under Bertrand competition for low product differentiation. Hence, the industry profit is higher under Bertrand competition.

Now consider the effects on the sum of the industry profit and the union utility, consumer surplus and welfare. Figure 2 plots $\frac{\beta\Delta(\pi+UN)}{(a-c-r)^2}$, $\frac{\beta\Delta CS}{(a-c-r)^2}$ and $\frac{\beta\Delta W}{(a-c-r)^2}$ for $\theta \in [0,1)$, where $\Delta\pi + \Delta UN = \left(\pi^{b,d,nf} - \pi^{c,d,nf}\right) + \left(UN^{b,d,nf} - UN^{c,d,nf}\right)$, $\Delta CS = CS^{b,d,nf} - CS^{c,d,nf}$ and $\Delta W = W^{b,d,nf} - W^{c,d,nf}$. See Appendix E for the expressions of $\frac{\beta\Delta(\pi+UN)}{(a-c-r)^2}$, $\frac{\beta\Delta CS}{(a-c-r)^2}$ and $\frac{\beta\Delta W}{(a-c-r)^2}$.

The following result follows from Figure 3.

Proposition 4.

(i) *The sum of the industry profit and the union utility are higher under Bertrand competition compared to Cournot competition for* $\theta > \theta^* = 0.418$ *(approx.).*
(ii) *Consumer surplus is higher under Bertrand competition compared to Cournot competition for* $\theta > \theta^{**} = 0.515$ *(approx.).*
(iii) *Welfare is higher under Bertrand competition compared to Cournot competition for* $\theta > \theta^{***} = 0.458$ *(approx.).*

It could be shown that the union utility is higher under Cournot competition compared to Bertrand competition. More intense competition under Bertrand competition compared to

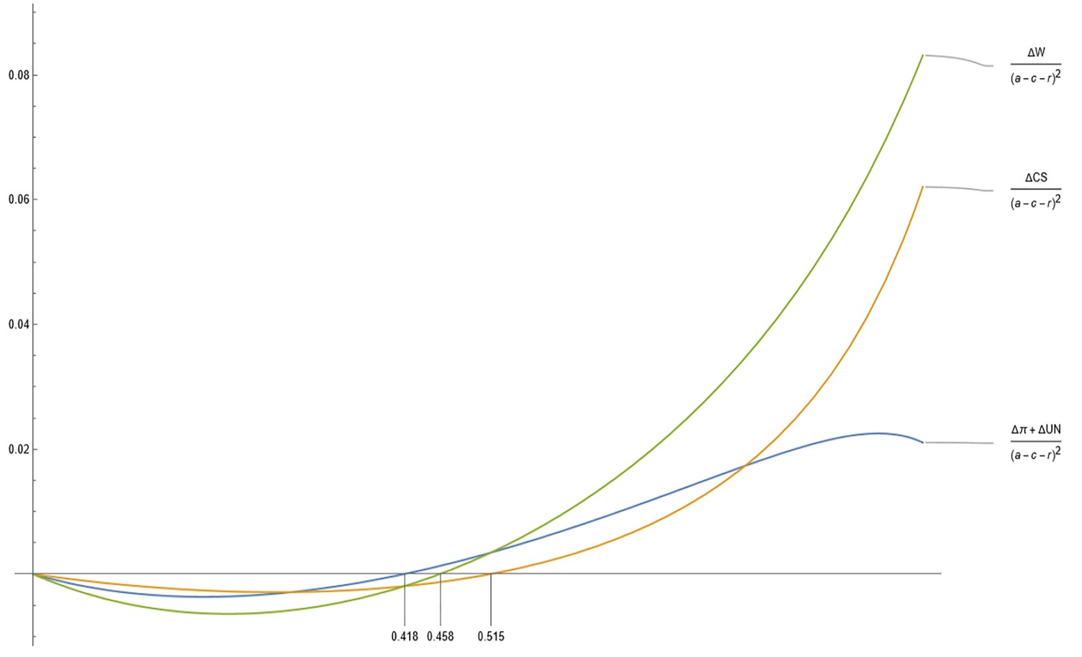

FIGURE 3 $\frac{\beta\Delta(\pi+UN)}{(a-c-r)^2}$, $\frac{\beta\Delta CS}{(a-c-r)^2}$ and $\frac{\beta\Delta W}{(a-c-r)^2}$ for $\theta \in [0,1)$.

Cournot competition does not allow the union to extract higher rent from the final goods producers under the former compared to the latter.

When taking the sum of the industry profit and the union utility, the effect of Bertrand competition (compared to Cournot competition) on the industry profit dominates (is dominated by) that of the union utility if the products are not very (very) differentiated. This happens because if the products are not very (very) differentiated, intense (not so intense) competition does not allow (allows) the union to extract significant rent from the firms. Hence, the sum of the industry profit and the union utility is higher (lower) under Bertrand competition compared to Cournot competition if the products are not very (very) differentiated.

The higher marginal cost of the non-integrated firm under Bertrand competition for high product differentiation creates the competition softening effect and reduces consumer surplus and welfare under Bertrand competition for high product differentiation.

Since consumer surplus and the sum of the industry profit and the union utility are higher (lower) under Bertrand competition compared to Cournot competition if the products are not sufficiently (sufficiently) differentiated, it is immediate that welfare will be higher (lower) under Bertrand competition compared to Cournot competition if the products are not sufficiently (sufficiently) differentiated.

6 | THE IMPLICATIONS OF POSITIVE BARGAINING POWER OF FIRMS

We have assumed in the above analysis that the unions determine wages. In other words, we have assumed that the unions have full bargaining power. Now we want to show the implications of positive bargaining power of the firms. Since the analysis with the positive bargaining power of the firms is very complicated under competition between Firms I and NI, we will consider some special cases to discuss the implications of bargaining power. We will argue here that vertical foreclosure will not occur for positive bargaining power of the unions. Further, since the equilibrium outcomes will be continuous with respect to the bargaining power, we will use continuity to say that our results on Cournot-Bertrand comparison will hold if the bargaining power of the unions are higher than a threshold level.

For the analysis of this section, we assume $a = \beta = 1$ and $c = r = 0$, since these parameters will not be crucial for the main analysis.

First consider the case of vertical foreclosure. Given the output of Firm I for a given wage rate, the union and the firm maximise $\underset{w}{Max}\left(U^f\right)^{\gamma}\left(\pi_I^f\right)^{1-\gamma}$, since the disagreement payoffs of both agents are zero, where $U^f = w_I L_I$ and $\pi_I^f = \left(1 - q_I^f - w_I\right)q_I^f$ are the utility of the union and the profit of Firm I, and γ and $(1-\gamma)$ are the respective bargaining power of the union and Firm I. We get the equilibrium wage as $\widehat{w}_I^f = \frac{\gamma}{2}$ and the equilibrium profit of Firm I as $\widehat{\pi}_I^f = \frac{(2-\gamma)^2}{16}$.

Now consider the case of no foreclosure and Cournot competition between Firms I and NI. We consider that both unions have bargaining power γ and both firms have bargaining power $(1-\gamma)$.

Given the outputs of the firms, the equilibrium wage for Firm I is determined by maximising $\underset{w_I}{Max}\left(U_I^d\right)^{\gamma}\left(\pi_I^{c,d,nf} - D\right)^{1-\gamma}$ where $U_I^d = w_I q_I^{c,d,nf}$ and $\pi_I^{c,d,nf} = \left(1 - \left(q_I^{c,d,nf} + \theta q_{NI}^{c,d,nf}\right) - w_I\right) q_I^{c,d,nf} + \alpha_{NI} q_{NI}^{c,d,nf}$ are the utility of the union and the profit of Firm I. While the disagreement payoff of the union is zero, the disagreement payoff of Firm I is $D = \widehat{\alpha}_{NI}^{c,d,nf}\widehat{q}_{NI}^{c,d,nf} = \frac{\widehat{\alpha}_{NI}^{c,d,nf}\left(2\left(1-\widehat{\alpha}_{NI}^{c,d,nf}-\widehat{w}_{NI}^{c,d,nf}\right)-\theta\left(1-\widehat{w}_I^{c,d,nf}\right)\right)}{\left(4-\theta^2\right)}$, where $\widehat{w}_I^{c,d,nf}$, $\widehat{w}_{NI}^{c,d,nf}$ and $\widehat{\alpha}_{NI}^{c,d,nf}$ are respectively the equilibrium wages for Firm I and Firm NI and the equilibrium intermediate goods price, as following Horn and Wolinsky (1988), we consider that Firm NI operates at the anticipated duopoly equilibrium in the case of disagreement between Firm I and the union it is facing.

The equilibrium intermediate goods price is determined by maximising $\underset{\alpha_{NI}}{Max}\pi_I^{c,d,nf}$. The equilibrium wage for Firm NI is determined by maximising $\underset{w_{NI}}{Max}\left(U_{NI}^d\right)^{\gamma}\left(\pi_{NI}^{c,d,nf}\right)^{1-\gamma}$ where $U_{NI}^d = w_{NI} q_{NI}^{c,d,nf}$ and $\pi_{NI}^{c,d,nf} = \left(1 - \left(\theta q_I^{c,d,nf} + q_{NI}^{c,d,nf}\right) - \alpha_{NI} - w_{NI}\right) q_{NI}^{c,d,nf}$ are the utility of the union faced by Firm NI and the profit of Firm NI, since the disagreement payoffs of both firm NI and the corresponding union are zero.

Since the general expressions of the equilibrium values are very complicated, we will consider two specific cases to show the implications of the union bargaining power. First, consider the case of $\gamma = 0$, that is, zero power of the union, but $\theta \in [0,1]$. In this case, the wages for both firms will be equal to the reservation wages, which are normalised to zero in this section. With zero wage rates for both firms, the equilibrium intermediate goods price is $\widehat{\alpha}_{NI}^{c,d,nf} = \frac{8-(4-\theta)\theta^2}{16-6\theta^2}$ and the equilibrium profit of Firm I is $\widehat{\pi}_I^{c,d,nf} = \frac{(6-\theta)(2-\theta)}{32-12\theta^2}$, which is equal to $\widehat{\pi}_I^f = \frac{1}{4}$ for $\theta = 1$ but greater than $\widehat{\pi}_I^f = \frac{1}{4}$ for $\theta \in [0,1)$. The profit of Firm NI is positive for $\theta \in [0,1)$. Hence, if the unions have no bargaining power, vertical foreclosure is not better if there is product differentiation. The reason is as follows. No foreclosure increases competition, while the differentiated product of Firm NI increases the market size. Since Firm I can control competiton through an appropriate intermediate goods price, it prefers no foreclosure if the products are differentiated.

Now consider the case of $\theta = 1$ but $\gamma \in [0,1]$. It can be found that the equilibrum wage rates and the intermediate goods price are $\widehat{w}_I^{c,d,nf} = \frac{(5-\gamma)(15+\gamma(28+\gamma(8-5\gamma))+(1+\gamma)\sqrt{(5-\gamma)(45-\gamma(75-\gamma(65-19\gamma)))}}{(1+\gamma)(270-\gamma(127-2\gamma(5+\gamma)))}$,
$\widehat{w}_{NI}^{c,d,nf} = \frac{3\gamma(15+\gamma(28+\gamma(8-5\gamma))-(1+\gamma)\sqrt{(5-\gamma)(45-\gamma(75+\gamma(-65+19\gamma)))}}{2(1+\gamma)(270-\gamma(127-2\gamma(5+\gamma)))}$,
$\widehat{\alpha}_{NI}^{c,d,nf} = \frac{255-\gamma(155-\gamma(2+7\gamma))+(1+\gamma)\sqrt{(5-\gamma)(45-\gamma(75+\gamma(-65+19\gamma)))}}{540-2\gamma(127-2\gamma(5+\gamma))}$.

If we calculate the equilibrium profit of Firm I with these equilibrium values and compare it with $\widehat{\pi}_I^f = \frac{(2-\gamma)^2}{16}$, we get $\widehat{\pi}_I^f = \widehat{\pi}_I^{c,d,nf}$ for $\gamma = 0$, $\widehat{\pi}_I^f < \widehat{\pi}_I^{c,d,nf}$ for $\gamma \in (0,1]$ and the profit of Firm NI is positive for $\gamma \in (0,1]$, implying that foreclosure will not occur for positive union power.[17] This happens since no foreclosure (compared to foreclosure) reduces rent extraction by the union in Firm I by creating indirect competition between the unions in Firms I and NI.

The above discussion suggests that foreclosure will not occur under Cournot competition for any $\theta \in [0,1]$ if $\gamma \in (0,1]$.[18]

Now consider Bertrand competition. The procedure for calculating the equilibrium wage rates and the equilibrium intermediate goods price is similar to that of under Cournot competition. So, we don't show those objective functions again.

First, consider the case of $\gamma = 0$ and $\theta \in [0,1)$. In this case, the wages for both firms are zero, the equilibrium intermediate goods price is $\widehat{\alpha}_{NI}^{b,d,nf} = \frac{8+\theta^3}{16+2\theta^2}$, and the equilibrium profit of Firm I is $\widehat{\pi}_I^{b,d,nf} = \frac{12+\theta(4+\theta+\theta^2)}{4(1+\theta)(8+\theta^2)}$, which is greater than $\widehat{\pi}_I^f = \frac{1}{4}$ for $\theta \in [0,1)$. The profit of Firm NI is positive for $\theta \in [0,1)$. Hence, if the unions have no bargaining power, Firm I does not prefer vertical foreclosure if there is product differentiation. The reason is similar to that of under Cournot competition.

Now if we consider $\theta \to 1$, say, $\theta = 0.999$, and $\gamma \in [0,1]$, it can be found that $\widehat{\pi}_I^f < \widehat{\pi}_I^{b,d,nf}$ for $\gamma \in [0,1]$ and the profit of Firm NI is positive for $\gamma \in [0,1]$, implying that foreclosure will not occur here.[19] The reason is similar to that of under Cournot competition.

Hence, we can get that foreclosure will not occur under Bertrand competition for any $\theta \in [0,1)$ if $\gamma \in [0,1]$. Thus, it shows that our no foreclosure result is not for $\gamma = 1$ only.

If $\gamma = 0$, the situation is similar to Arya et al. (2008), which showed that Bertrand competition creates higher industry profit, lower consumer surplus and lower welfare compared to Cournot competition. On the other hand, we showed our result with $\gamma = 1$. Since the wage rates, intermediate goods prices, profits, consumer surplus and welfare are continuous in γ, it is immediate from continuity that our results on Cournot-Bertrand comparison will hold if the values of γ are higher than some threshold levels. The threshold levels are given by the equality of the equilibrium values under Cournot and Bertrand competition. Since the equilibrium expressions are different for profit, consumer surplus and welfare, the threshold values will be different for the comparisons of profit, consumer surplus and welfare.

[17]We are not reporting the equilibrium profit of Firm I due to a very long expression.

[18]Rather than the way we showed it, one can use the 'Mathematica' software to show it under Cournot competition with the general expressions for $\theta \in [0,1]$ if $\gamma \in [0,1]$.

[19]Due to the extremely long expressions of the equilibrium values, we are not reporting them here.

7 | CONCLUSION

We contribute to the literature by showing the effects of price and quantity competition in an industry with complementary inputs, outsourcing and a vertically integrated firm where vertical integration occurs between a final goods producer and a subset of input suppliers. We show that the profit of the integrated firm and the industry profit are higher under Bertrand competition, the profit of the non-integrated firm is higher under Bertrand competition for higher product differentiation, and consumer surplus and welfare are higher under Bertrand competition for low product differentiation. Thus, the presence of complementary inputs provides new insights.

Our analysis also shows that no market foreclosure can be the preferred choice of the vertically integrated firm for any degree of product differentiation. For example, as shown with the full bargaining power of the unions, the vertically integrated firm always prefers no market foreclosure. Thus, we show that the usual concern about market foreclosure following vertical integration may not be valid in the presence of complementary inputs when vertical integration involves a subset of input suppliers.

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CONFLICT OF INTEREST STATEMENT

None.

REFERENCES

Acharyya, R., & Marjit, S. (1998). To liberalize or not to liberalize an LDC-market with an inefficient incumbent. *International Review of Economics & Finance*, *7*(3), 277–296. https://doi.org/10.1016/s1059-0560(99)80032-x

Arya, A., Mittendorf, B., & Sappington, D. E. M. (2008). Outsourcing, vertical integration, and price vs. quantity competition. *International Journal of Industrial Organization*, *26*, 1–16. https://doi.org/10.1016/j.ijindorg.2006.10.006

Bester, H., & Petrakis, E. (1993). The incentives for cost reduction in a differentiated industry. *International Journal of Industrial Organization*, *11*(4), 519–534. https://doi.org/10.1016/0167-7187(93)90023-6

Bonanno, G., & Haworth, B. (1998). Intensity of competition and the choice between product and process innovation. *International Journal of Industrial Organization*, *16*(4), 495–510. https://doi.org/10.1016/s0167-7187(97)00003-9

Boone, J. (2001). The intensity of competition and the incentive to innovate. *International Journal of Industrial Organization*, *19*(5), 705–726. https://doi.org/10.1016/s0167-7187(00)00090-4

Cellini, R., Lambertini, L., & Ottaviano, G. I. P. (2004). Welfare in a differentiated oligopoly with free entry: A cautionary note. *Research in Economics*, *58*(2), 125–133. https://doi.org/10.1016/s1090-9443(04)00013-4

Choi, J. P. (2010). Patent pools and cross-licensing in the shadow of patent litigation. *International Economic Review*, *51*(2), 441–460. https://doi.org/10.1111/j.1468-2354.2010.00587.x

Chongvilaivan, A., Hur, J., & Riyanto, Y. E. (2013). Labor union bargaining and firm organizational structure. *Labour Economics*, *24*, 116–124. https://doi.org/10.1016/j.labeco.2013.08.001

Delbono, F., & Denicolò, V. (1990). R&D investment in a symmetric and homogeneous oligopoly. *International Journal of Industrial Organization*, *8*(2), 297–313. https://doi.org/10.1016/0167-7187(90)90022-s

Dowrick, S. (1989). Union-oligopoly bargaining. *Economic Journal*, *99*(398), 1123–1142. https://doi.org/10.2307/2234092

Flanagan, R. J. (1999). Macroeconomic performance and collective bargaining: An international perspective. *Journal of Economic Literature*, *37*(3), 1150–1175. https://doi.org/10.1257/jel.37.3.1150

Ghosh Dastidar, K. (1997). Comparing Cournot and Bertrand in a homogeneous product market. *Journal of Economic Theory*, *75*(1), 205–212. https://doi.org/10.1006/jeth.1997.2268

Häckner, J. (2000). A note on price and quantity competition in differentiated oligopolies. *Journal of Economic Theory*, *93*(2), 233–239. https://doi.org/10.1006/jeth.2000.2654

Hart, O., Tirole, J., Carlton, D. W., & Williamson, O. E. (1990). Vertical integration and market foreclosure. *Brookings Papers on Economic Activity. Microeconomics*, *1990*, 205–286. 1990. https://doi.org/10.2307/2534783

Harrison, D., & Ludwig, C. (2021). Electric Vehicle Battery Supply Chain Analysis-How Battery Demand and Production Are Reshaping the Automotive Industry. Automotive from Ultima Media, 2–26.

Haucap, J., & Wey, C. (2004). Unionisation structures and innovation incentives. *Economic Journal*, *114*(494), C149–C165. https://doi.org/10.1111/j.0013-0133.2004.00203.x

Horn, H., & Wolinsky, A. (1988). Bilateral monopolies and incentives for merger. *The RAND Journal of Economics*, *19*(3), 408–419. https://doi.org/10.2307/2555664

IEA. (2022). Global EV Outlook 2022- Securing supplies for an electric future. Paris.

IEA. (2023). Global EV outlook 2023- catching up with climate ambitions. Paris.

Lerner, J., & Tirole, J. (2004). Efficient patent pools. *The American Economic Review*, *94*(3), 692–711. https://doi.org/10.1257/0002828041464641

Lommerud, K. E., Meland, F., & Sørgard, L. (2003). Unionised oligopoly, trade liberalisation and location choice. *Economic Journal*, *113*(490), 782–800. https://doi.org/10.1111/1468-0297.t01-1-00154

López, M. C. (2007). Price and quantity competition in a differentiated duopoly with upstream suppliers. *Journal of Economics and Management Strategy*, *16*(2), 469–505. https://doi.org/10.1111/j.1530-9134.2007.00146.x

López, M. C., & Naylor, R. A. (2004). The Cournot-Bertrand profit differential: A reversal result in a differentiated duopoly with wage bargaining. *European Economic Review*, *48*(3), 681–696. https://doi.org/10.1016/s0014-2921(02)00326-4

Moresi, S., & Schwartz, M. (2017). Strategic incentives when supplying to rivals with an application to vertical market structure. *International Journal of Industrial Organization*, *51*, 137–161. https://doi.org/10.1016/j.ijindorg.2016.12.005

Mukherjee, A. (2005). Price and quantity under free entry. *Research in Economics*, *59*(4), 335–344. https://doi.org/10.1016/j.rie.2005.09.005

Mukherjee, A. (2008). Unionised labour market and strategic production decisions of a multinational. *Economic Journal*, *118*(532), 1621–1639. https://doi.org/10.1111/j.1468-0297.2008.02183.x

Mukherjee, A. (2010). Competition and welfare: The implications of licensing. *The Manchester School*, *78*(1), 20–40. https://doi.org/10.1111/j.1467-9957.2009.02126.x

Mukherjee, A. (2011). Competition, innovation and welfare. *The Manchester School*, *79*(6), 1945–1057. https://doi.org/10.1111/j.1467-9957.2010.02184.x

Mukherjee, A., Broll, U., & Mukherjee, S. (2012). Bertrand versus Cournot competition in a vertical structure: A note. *The Manchester School*, *80*(5), 545–559. https://doi.org/10.1111/j.1467-9957.2012.02228.x

Mukherjee, A., & Pennings, E. (2011). Unionization structure, licensing and innovation. *International Journal of Industrial Organization*, *29*(2), 232–241. https://doi.org/10.1016/j.ijindorg.2010.06.001

Naylor, R. (1998). International trade and economic integration when labour markets are generally unionised. *European Economic Review*, *42*(7), 1251–1267. https://doi.org/10.1016/s0014-2921(97)00075-5

OECD. (2004). *OECD employment outlook*. OECD Publishing.

OECD. (2018). *OECD employment outlook*. OECD Publishing.

Osipchuk, E. (2018). Working competition and biotechnology patent pools. *Stockholm Intellectual Property Law Review*, *1*, 28–43.

Qiu, L. D. (1997). On the dynamic efficiency of Bertrand and Cournot equilibria. *Journal of Economic Theory*, *75*(1), 213–229. https://doi.org/10.1006/jeth.1997.2270

Quan, X. I., Loon, M., & Sanderson, J. (2018). Innovation in the local context: A case study of BYD in China. *International Journal of Innovation and Technology Management*, *15*(02), 1850017. https://doi.org/10.1142/s0219877018500177

Reisinger, M., & Tarantino, E. (2019). Patent pools, vertical integration, and downstream competition,'. *The RAND Journal of Economics*, *50*(1), 168–200. https://doi.org/10.1111/1756-2171.12266

Rey, P., & Tirole, J. (2007). A premier on foreclosure. In M. Armstrong & R. Porter (Eds.), *Handbook of industrial organization, 3* (pp. 2145–2220). University of California Press.

Reynolds, S. S., & Isaac, R. M. (1992). Stochastic innovation and product market organization. *Economic Theory*, *2*(4), 525–545. https://doi.org/10.1007/bf01212475

Rong, K., Shi, Y., Shang, T., Chen, Y., & Hao, H. (2017). Organizing business ecosystems in emerging electric vehicle industry: Structure, mechanism, and integrated configuration. *Energy Policy*, *107*, 234–247. https://doi.org/10.1016/j.enpol.2017.04.042

Salinger, M. A. (1988). Vertical mergers and market foreclosure. *Quarterly Journal of Economics*, *103*(2), 345–356. https://doi.org/10.2307/1885117

Shapiro, C. (2001). Navigating the patent thicket: Cross licenses, patent pools, and standard-setting. In A. Jaffe, J. Lerner, & S. Stern (Eds.), *Innovation policy and the economy* (Vol. 1). MIT-Press.

Singh, N., & Vives, X. (1984). Price and quantity competition in a differentiated duopoly. *The RAND Journal of Economics*, *15*(4), 546–554. https://doi.org/10.2307/2555525

Straume, O. R. (2002). Union collusion and intra-industry trade. *International Journal of Industrial Organization*, *20*(5), 631–652. https://doi.org/10.1016/s0167-7187(01)00091-1

Symeonidis, G. (2003). Comparing Cournot and Bertrand equilibria in a differentiated duopoly with product R&D. *International Journal of Industrial Organization*, *21*(1), 39–55. https://doi.org/10.1016/s0167-7187(02)00052-8

Trappey, C. V., Trappey, A. J. C., & Wang, Y.-H. (2016). Are patent trade wars impeding innovation and development? *World Patent Information*, *46*, 64–72. https://doi.org/10.1016/j.wpi.2016.06.004

Zanchettin, P. (2006). Differentiated duopoly with asymmetric costs. *Journal of Economics and Management Strategy*, *15*(4), 999–1015. https://doi.org/10.1111/j.1530-9134.2006.00125.x

Zanchettin, P., & Mukherjee, A. (2017). Vertical integration and product differentiation. *International Journal of Industrial Organization*, *55*, 25–57. https://doi.org/10.1016/j.ijindorg.2017.07.004

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APPENDIX A

Proposition A1. *We get from (2) and (5) that*

$$\Delta\pi_I(c,nf-f) = \widehat{\pi}_I^{c,d,nf} - \widehat{\pi}_I^{f} = \frac{(a-c-r)^2\left(-1+\frac{8(2-\theta)(272+\theta(56-\theta(4+\theta)(28-\theta(2+\theta))))}{(48-18\theta^2+\theta^4)^2}\right)}{16\beta}.$$

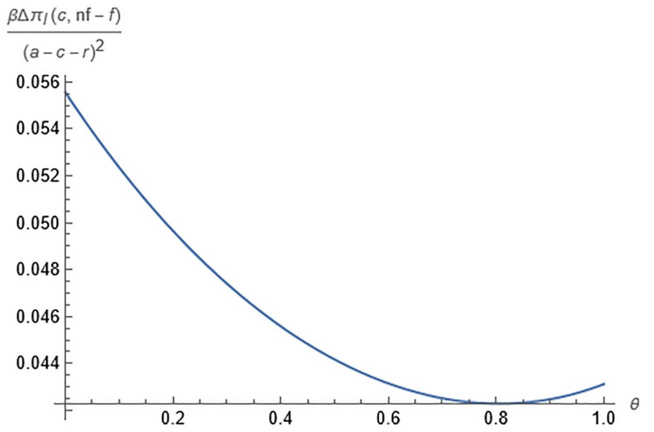

FIGURE A1 The relationship between $\frac{\beta\Delta\pi_I(c,nf-f)}{(a-c-r)^2}$ and θ.

Figure A1, which plots $\frac{\beta\Delta\pi_I(c,nf-f)}{(a-c-r)^2}$ for different values of θ, shows that the profit of the integrated firm under Cournot competition is higher under no vertical foreclosure compared to vertical foreclosure for $\theta \in [0,1]$.

APPENDIX B

Proposition B2. *We get from (2) and (14) that*

$$\Delta\pi_I(b,nf-f) = \widehat{\pi}_I^{b,d,nf} - \widehat{\pi}_I^{f}$$

$$= \frac{(a-c-r)^2\left(-1+\frac{4(2+\theta)\left(2-\theta^2\right)^2\left(\begin{array}{c}544+\theta(304-\theta(240+\theta(56+\theta(52+\\ \theta(46-\theta(24+\theta(5+3\theta)))))))\end{array}\right)}{(1+\theta)\left(96-76\theta^2+8\theta^6-\theta^8\right)^2}\right)}{16\beta}.$$

Figure B1, which plots $\frac{\beta\Delta\pi_I(b,nf-f)}{(a-c-r)^2}$ for different values of θ, shows that the profit of the integrated firm under Bertrand competition is higher under no vertical foreclosure compared to vertical foreclosure for $\theta \in [0,1)$.

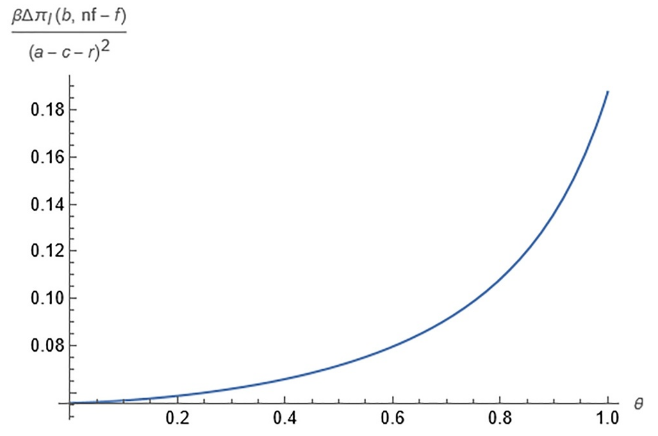

FIGURE B1 The relationship between $\frac{\beta\Delta\pi_I(b,nf-f)}{(a-c-r)^2}$ and θ.

APPENDIX C

Lemma C1. *We get*

$$\Delta\widehat{w}_I = \widehat{w}_I^{b,d,nf} - \widehat{w}_I^{c,d,nf} = \frac{(a-c-r)(-2+\theta)\theta(2+\theta)(192+\theta(48+\theta(-176+\theta(16+\theta(60+\theta(7+\theta)(-4+\theta(-1+\theta)))))))}{\left(48-18\theta^2+\theta^4\right)\left(96-76\theta^2+8\theta^6-\theta^8\right)}.$$

Figure C1, which plots $\frac{\Delta\widehat{w}_I}{(a-c-r)}$ for different values of θ, shows that wage for the integrated firm is lower under Bertrand competition compared to Cournot competition for $0 < \theta < 1$.

We get

$$\Delta\widehat{w}_{NI} = \widehat{w}_{NI}^{b,d,nf} - \widehat{w}_{NI}^{c,d,nf} = \frac{(a-c-r)\theta^2\left(-4+\theta^2\right)^2(32+\theta(-40+\theta(-40+\theta(12+\theta(7+2\theta)))))}{2\left(48-18\theta^2+\theta^4\right)\left(96-76\theta^2+8\theta^6-\theta^8\right)}.$$

We get

$$\Delta\widehat{\alpha}_{NI} = \widehat{\alpha}_{NI}^{b,d,nf} - \widehat{\alpha}_{NI}^{c,d,nf} = \frac{(a-c-r)\theta^2\begin{pmatrix}-256+\theta(320+\theta(768+\theta(-368+\theta(-616+\\ \theta(176+\theta(196+\theta(-36+\theta(-25+\theta(2+\theta)))))))))\end{pmatrix}}{2\left(48-18\theta^2+\theta^4\right)\left(96-76\theta^2+8\theta^6-\theta^8\right)}.$$

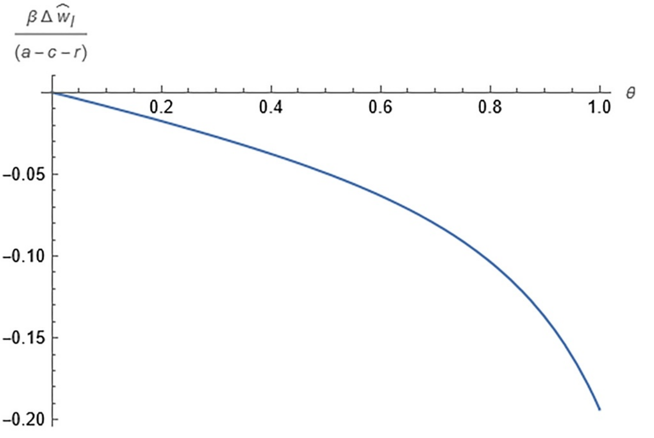

FIGURE C1. The relationship between $\frac{\Delta \widehat{w}_I}{(a-c-r)}$ and θ.

We get

$$\Delta \widehat{MC}_{NI} = \left(\widehat{w}_{NI}^{b,d,nf} + \widehat{\alpha}_{NI}^{b,d,nf}\right) - \left(\widehat{w}_{NI}^{c,d,nf} + \widehat{\alpha}_{NI}^{c,d,nf}\right)$$
$$= \frac{(a-c-r)\theta^2 \left(\begin{array}{c} 256 + \theta(-320 + \theta(-128 \\ + \theta(2+\theta)(72 + \theta(-112 + \theta(92 + \theta(4 + \theta(-22 + \theta(2+\theta))))))) \end{array}\right)}{2\left(48 - 18\theta^2 + \theta^4\right)\left(96 - 76\theta^2 + 8\theta^6 - \theta^8\right)}.$$

APPENDIX D

Proposition D3. *(i) We get*

$$\Delta \pi_I = \widehat{\pi}_I^{b,d,nf} - \widehat{\pi}_I^{c,d,nf}$$
$$= \frac{(a-c-r)^2}{4\beta}\left(\begin{array}{l} \dfrac{2(-2+\theta)(272+\theta(56+\theta(4+\theta)(-28+\theta(2+\theta))))}{\left(48-18\theta^2+\theta^4\right)^2} \\ + \dfrac{(2+\theta)(-2+\theta^2)^2(544+\theta(304+\theta(-240+\theta(-56+\theta(-52+\theta(-46+\theta(24+\theta(5+3\theta))))))))}{(1+\theta)\left(96-76\theta^2+8\theta^6-\theta^8\right)^2} \end{array}\right).$$

Figure D1, which plots $\frac{\beta \Delta \pi_I}{(a-c-r)^2}$ for different values of θ, shows that the integrated firm earns higher profit under Bertrand competition compared to Cournot competition for $0 < \theta < 1$.

(ii) We get

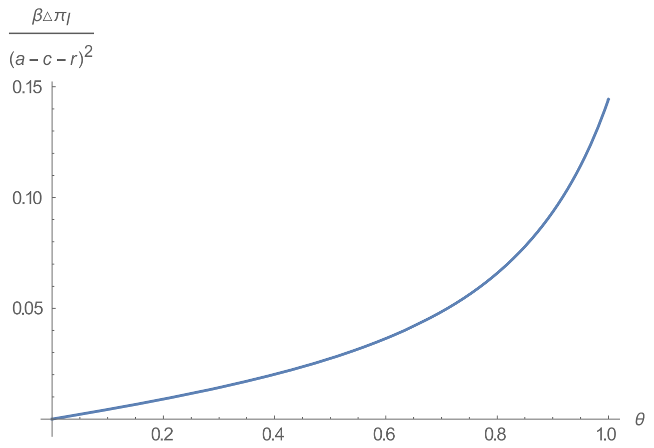

FIGURE D1 The relationship between $\frac{\beta\Delta\pi_I}{(a-c-r)^2}$ and θ.

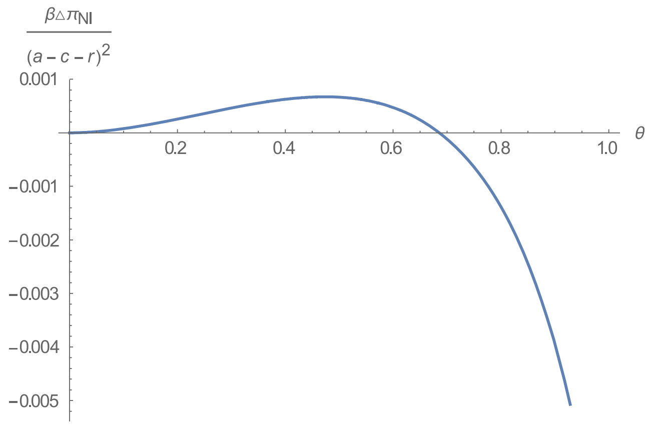

FIGURE D2 The relationship between $\frac{\beta\Delta\pi_{NI}}{(a-c-r)^2}$ and θ.

$$\Delta\pi_{NI} = \widehat{\pi}_{NI}^{b,d,nf} - \widehat{\pi}_{NI}^{c,d,nf}$$

$$= \frac{(a-c-r)^2 \left(\begin{array}{c} (-1+\theta)(-2+\theta^2)^2(2+\theta^2)^2 \\ \dfrac{4(-8+\theta(4+\theta))^2}{(48-18\theta^2+\theta^4)^2} - \dfrac{(-8+(-1+\theta)\theta(4+\theta))^2}{(1+\theta)(96-76\theta^2+8\theta^6-\theta^8)^2} \end{array} \right)}{4\beta}.$$

Figure D2, which plots $\frac{\beta\Delta\pi_{NI}}{(a-c-r)^2}$ for different values of θ, shows that the non-integrated firm earns higher profit under Bertrand competition compared to Cournot competition for $\theta < \theta = 0.686$ (approx.).

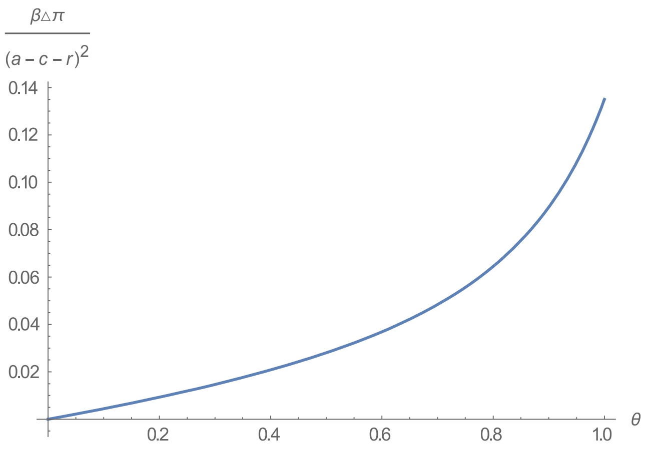

FIGURE D3 The relationship between $\frac{\beta\Delta\pi}{(a-c-r)^2}$ and θ.

(iii) We get

$$\Delta\pi = \left(\frown{\pi}_I^{b,d,nf} + \frown{\pi}_{NI}^{b,d,nf}\right) - \left(\frown{\pi}_I^{c,d,nf} + \frown{\pi}_{NI}^{c,d,nf}\right)$$

$$= \frac{(a-c-r)^2}{4\beta}\left(\frac{2(-672+\theta(288+\theta(280+\theta(-88+\theta(-34+\theta(4+\theta))))))}{\left(48-18\theta^2+\theta^4\right)^2} - \frac{(-2+\theta^2)^2(-1344+\theta(-1152+\theta(304+\theta(384+\theta(316+\theta(156+\theta(-50+\theta(-42+\theta(4+\theta)(-8+\theta+\theta^2)))))))))}{(1+\theta)\left(96-76\theta^2+8\theta^6-\theta^8\right)^2}\right).$$

Figure D3, which plots $\frac{\beta\Delta\pi}{(a-c-r)^2}$ for different values of θ, shows that the industry profit is higher under Bertrand competition than that of under Cournot competition for $0 < \theta < 1$.

APPENDIX E

Proposition E4. *We derive* $\Delta\pi + \Delta UN = (\pi^{b,d,nf} - \pi^{c,d,nf}) + (UN^{b,d,nf} - UN^{c,d,nf})$

Where $\Delta\pi$ is given in Appendix D (iii) and

$$
\begin{aligned}
\Delta UN &= UN^{b,d,nf} - UN^{c,d,nf} \\
&= \frac{1}{4\beta}\left(-a+c+r\right)^{2}\left(-2+\theta\right)\left(2+\theta\right)\left(\frac{2\left(208+\theta\left(2+\theta\right)\left(4+\theta\right)\left(-14+5\theta\right)\right)}{\left(48-18\theta^{2}+\theta^{4}\right)^{2}} - \frac{\left(-1+\theta\right)\left(-2+\theta^{2}\right)\left(832+\theta\left(832+\theta\left(80+\theta\left(96+\theta\left(-92+\theta\left(-232+\theta\left(-52+\theta\left(1+\theta\right)\right)\left(-8+\theta\left(9+5\theta\right)\right)\right)\right)\right)\right)\right)\right)}{\left(\left(1+\theta\right)\left(-96+76\theta^{2}-8\theta^{6}+\theta^{8}\right)^{2}\right)}\right).
\end{aligned}
$$

We get

$$
\begin{aligned}
\Delta CS &= CS^{b,d,nf} - CS^{c,d,nf} \\
&= \frac{(a-c-r)^{2}}{8\beta}\left(-\frac{4(208+\theta(80-\theta(172+\theta(24-\theta(25+4\theta)))))}{\left(48-18\theta^{2}+\theta^{4}\right)^{2}} + \frac{\left(2-\theta^{2}\right)^{2}\left(832+\theta(768+\theta(80+\theta(176-\theta(124+\theta(252+\theta(24+\theta(1+\theta)(16-\theta(13+4\theta)))))))\right)}{(1+\theta)\left(96-76\theta^{2}+8\theta^{6}-\theta^{8}\right)^{2}}\right).
\end{aligned}
$$

We get

$$
\begin{aligned}
\Delta W &= W^{b,d,nf} - W^{c,d,nf} \\
&= \frac{(a-c-r)^{2}}{8\beta}\left(\frac{4(-1712+\theta(656+\theta(836-\theta(240+\theta(123-2\theta(8+3\theta))))))}{\left(48-18\theta^{2}+\theta^{4}\right)^{2}} + \frac{\left(2-\theta^{2}\right)\left(13696+\theta(6144-\theta(12256+\theta(4128+\theta(984+\theta(1688-\theta(2724+\theta(1332-\theta(242+\theta(2+\theta(163+\theta(95-12\theta(2+\theta))))))))))))\right)}{(1+\theta)\left(96-76\theta^{2}+8\theta^{6}-\theta^{8}\right)^{2}}\right).
\end{aligned}
$$

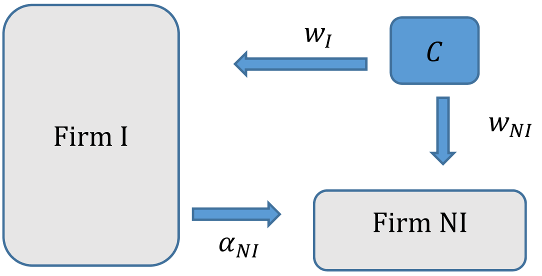

FIGURE F1 Centralised union.

APPENDIX F

The case of a centralised labour union

The purpose of this section is to show that the results derived under decentralised unions hold under a centralised union. We consider in this section a model similar to Section 2 with the exception that a single labour union supplies workers and charges wages to both Firms I and NI. The structure of the industry is shown in the following Figure F1.

Since only Firm I produces under vertical foreclosure, the analysis under foreclosure will be similar to the one shown in subsection 2.1.

F.1 | No vertical foreclosure: Cournot competition

If there is no vertical foreclosure, the equilibrium outputs of Firm I and Firm NI are respectively $q_I^{c,c,nf} = \frac{2(a-c-w_I)-\theta(a-\alpha_{NI}-w_{NI})}{\beta(4-\theta^2)}$ and $q_{NI}^{c,c,nf} = \frac{2(a-\alpha_{NI}-w_{NI})-\theta(a-c-w_I)}{\beta(4-\theta^2)}$.

A centralised union maximises its utility function $U^c(w,L) = (w_I - r)L_I + (w_{NI} - r)L_{NI}$, with respect to w_I and w_{NI}, and Firm I maximises $\pi_I^{c,c,nf} = (a - \beta(q_I + \theta q_{NI}) - c - w_I)q_I + (\alpha_{NI} - c)q_{NI}$, with respect to α_{NI}. The intermediate goods price and the wages are determined simultaneously.

We get the equilibrium intermediate goods price and wages under a centralised union as

$$\widehat{\alpha}_{NI}^{c,c,nf} = \frac{8(a+2c-r) - 4(a+c-r)\theta^2 + (a-c-r)\theta^3}{8\left(3-\theta^2\right)}$$

$$\widehat{w}_I^{c,c,nf} = \frac{a-c+r}{2},$$

$$\widehat{w}_{NI}^{c,c,nf} = \frac{16(a-c+2r) - 4(a-c+3r)\theta^2 - (a-c-r)\theta^3}{16\left(3-\theta^2\right)}.$$

Given the equilibrium intermediate goods price and wages, the equilibrium outputs of Firms I and NI under a centralised union are $\widehat{q}_I^{c,c,nf} = \frac{(a-c-r)(2-\theta)(6+\theta)}{16\beta\left(3-\theta^2\right)}$ and $\widehat{q}_{NI}^{c,c,nf} = \frac{(a-c-r)(4-3\theta)}{8\beta\left(3-\theta^2\right)}$, and the corresponding profits are

$$\widehat{\pi}_I^{c,c,nf} = \frac{(a-c-r)^2(2-\theta)(136-\theta(28+\theta(50-11\theta)))}{256\beta\left(3-\theta^2\right)^2}, \tag{F1}$$

$$\widehat{\pi}_{NI}^{c,c,nf} = \frac{(a-c-r)^2(4-3\theta)^2}{64\beta\left(3-\theta^2\right)^2}. \tag{F2}$$

The equilibrium consumer surplus and welfare are respectively

$$CS^{c,c,nf} = \frac{(a-c-r)^2\left(208-\theta^2(180-\theta(40+13\theta))\right)}{512\beta\left(3-\theta^2\right)^2} \tag{F3}$$

$$W^{c,c,nf} = \frac{(a-c-r)^2(1712-\theta(960+\theta(556-\theta(280+19\theta))))}{512\beta\left(3-\theta^2\right)^2}. \tag{F4}$$

Proposition 5. *Under Cournot competition, if the integrated and non-integrated firms hire workers from a centralised labour union, the integrated firm supplies the intermediate good to the non-integrated firm for any degree of production differentiation, that is, for θ ∈ [0,1], implying that the integrated firm prefers no foreclosure.*

Proof: We get from (2) and (*F*1) that $\widehat{\pi}_I^{c,c,nf} - \widehat{\pi}_I^f = \frac{(a-c-r)^2(4-3\theta)^2\left(8-3\theta^2\right)}{256\beta\left(3-\theta^2\right)^2} > 0$. ∎

Proposition 5 is similar to Proposition 1. Hence, no foreclosure under Cournot competition occurs under both decentralised and centralised unions.

If there is a centralised union, Firm I pays the same wage, $\widehat{w}_I^{c,c,nf} = \widehat{w}_I^f = \frac{a-c+r}{2}$, under no foreclosure and foreclosure. However, the wage rate paid by Firm NI, which is $\widehat{w}_{NI}^{c,c,nf} = \frac{16(a-c+2r)-4(a-c+3r)\theta^2-(a-c-r)\theta^3}{16\left(3-\theta^2\right)}$, is lower than that of under foreclosure. Hence, no foreclosure helps to produce the product in Firm NI at a lower wage and Firm I can extract some of this benefit by charging an appropriate price for the intermediate goods. As a result, Firm I prefers no foreclosure under a centralised union for any degree of product differentiation.

F.2 | No foreclosure: Bertrand competition

If there is no vertical foreclosure, the equilibrium prices charged by Firm I and Firm NI are respectively $P_I^{b,c,nf} = \frac{2(a+c+w_I)-\theta(a+2c-3\alpha_{NI}-w_{NI})-a\theta^2}{4-\theta^2}$, $P_{NI}^{b,c,nf} = \frac{2(a+\alpha_{NI}+w_{NI})-\theta(a-c-w_I)-(a+c-\alpha_{NI})\theta^2}{4-\theta^2}$, and the corresponding equilibrium outputs are $q_I^{b,c,nf} = \frac{-2(c+w_I)-a\left(-2+\theta+\theta^2\right)+\theta\left(w_{NI}+w_I\theta+c\left(2+\theta-\theta^2\right)+\alpha_{NI}\left(-1+\theta^2\right)\right)}{\beta\left(4-5\theta^2+\theta^4\right)}$ and $q_{NI}^{b,c,nf} = \frac{-2(w_{NI}+\alpha_{NI})+\theta(c+w_I-c\theta+\theta(w_{NI}+2\alpha_{NI}))-a\left(-2+\theta+\theta^2\right)}{\beta\left(4-5\theta^2+\theta^4\right)}$.

A centralised union maximises its utility $U^c(w,L) = (w_I - r)L_I + (w_{NI} - r)L_{NI}$, with respect to w_I and w_{NI}, and Firm I maximises $\pi_I^{b,c,nf} = (a - \beta(q_I + \theta q_{NI}) - c - w_I)q_I + (\alpha_{NI} - c)q_{NI}$, with respect to α_{NI}. The intermediate goods price and the wages are determined simultaneously.

The equilibrium intermediate goods price and the wages can be found as

$$\widehat{\alpha}_{NI}^{b,c,nf} = c + \frac{(a-c-r)\left(8+\theta^3\right)}{24+4\theta^2-\theta^4},$$

$$\widehat{w}_I^{b,c,nf} = \frac{12(a-c-r) - 4(a-c-r)\theta + 2(a-c-r)\theta^2 - (a-c)\theta^4}{24 + 4\theta^2 - \theta^4},$$

$$\widehat{w}_{NI}^{b,c,nf} = \frac{1}{2}\left(a - c + r - \frac{(a-c-r)\left(8+\theta^3\right)}{24+4\theta^2-\theta^4}\right).$$

Given the equilibrium intermediate goods price and the wages, we get the equilibrium prices changed by Firms I and NI respectively as

$$\widehat{P}_I^{b,c,nf} = \frac{a\left(36 + \theta^2\left(3 - \theta - 2\theta^2\right)\right) + (c+r)\left(12 + \theta^2(5+\theta)\right)}{2\left(24 + 4\theta^2 - \theta^4\right)},$$

$$\widehat{P}_{NI}^{b,c,nf} = \frac{a\left(20 - \theta\left(3 - \theta\left(3 - \theta - \theta^2\right)\right)\right) + (c+r)\left(4 + \theta\left(3 + \theta + \theta^2\right)\right)}{24 + 4\theta^2 - \theta^4}.$$

The corresponding equilibrium outputs are

$$\widehat{q}_I^{b,c,nf} = \frac{(a-c-r)(2+\theta)(6-\theta(1-2\theta))}{2\beta(1+\theta)\left(24+4\theta^2-\theta^4\right)},$$

$$\widehat{q}_{NI}^{b,c,nf} = \frac{(a-c-r)(4+\theta)\left(2+\theta^2\right)}{2\beta(1+\theta)\left(24+4\theta^2-\theta^4\right)}.$$

The equilibrium profits are

$$\widehat{\pi}_I^{b,c,nf} = \frac{(a-c-r)^2(2+\theta)(136+\theta(20+\theta(50+\theta(7+3\theta))))}{4\beta(1+\theta)\left(24+4\theta^2-\theta^4\right)^2}. \tag{F5}$$

$$\widehat{\pi}_{NI}^{b,c,nf} = \frac{(a-c-r)^2(1-\theta)(4+\theta)^2\left(2+\theta^2\right)^2}{4\beta(1+\theta)\left(24+4\theta^2-\theta^4\right)^2} \tag{F6}$$

The equilibrium consumer surplus and welfare are respectively.

$$CS^{b,c,nf} = \frac{(a-c-r)^2\left(208+\theta\left(112+\theta\left(156+\theta\left(108+\theta\left(37+\theta\left(23+4\theta\right)\right)\right)\right)\right)\right)}{8\beta(1+\theta)\left(24+4\theta^2-\theta^4\right)^2}, \tag{F7}$$

$$W^{b,c,nf} = \frac{(a-c-r)^2\left(1712+\theta\left(464+\theta\left(836+\theta\left(276-\theta\left(5-\theta\left(1-4\theta\left(8+3\theta\right)\right)\right)\right)\right)\right)\right)}{8\beta(1+\theta)\left(24+4\theta^2-\theta^4\right)^2}. \tag{F8}$$

Proposition 6. *Under Bertrand competition, if the integrated and the non-integrated firms hire workers from a centralised labour union, the integrated firm supplies the intermediate good to the non-integrated firm for $\theta \in [0,1)$, implying that the integrated firm prefers no foreclosure.*

Proof: We get from (2) and ($F5$)

$$\widehat{\pi}_I^{b,c,nf} - \widehat{\pi}_I^{f} = \frac{(a-c-r)^2\left(-1+\frac{4(2+\theta)(136+\theta(20+\theta(50+\theta(7+3\theta))))}{(1+\theta)\left(24+4\theta^2-\theta^4\right)^2}\right)}{16\beta} > 0,$$

Which implies that if there is a centralised union, Firm I prefers no vertical foreclosure compared to vertical foreclosure. ■

Since $\widehat{w}_I^{f} - \widehat{w}_I^{b,c,nf} = \frac{(a-c-r)\theta\left(8+\theta^3\right)}{2\left(24+4\theta^2-\theta^4\right)} > 0$, it shows that no vertical foreclosure reduces the wage paid by Firm I compared to vertical foreclosure. This benefit makes Firm I better off under no vertical foreclosure compared to foreclosure.

F.3 | Comparing profits, consumer surplus and welfare

Now we compare the profits, consumer surplus and welfare under Cournot and Bertrand competition.

Proposition 7.

(i) *The profit of the integrated firm is higher under Bertrand competition compared to Cournot competition for* $\theta \in (0,1)$.
(ii) *The profit of the non-integrated firm is higher under Bertrand competition compared to Cournot competition for* $\theta < 0.726$ *(approx.).*
(iii) *The industry profit is higher under Bertrand competition compared to Cournot competition for* $\theta \in (0,1)$.
(iv) *Consumer surplus is higher under Bertrand competition compared to Cournot competition for* $\theta > \theta^{***} = 0.547$ *(approx.).*
(v) *Welfare is higher under Bertrand competition compared to Cournot competition for* $\theta > \theta^{****} = 0.469$ *(approx.).*

Proof:

(i) We get

$$\Delta\pi_I' = \widehat{\pi}_I^{b,c,nf} - \widehat{\pi}_I^{c,c,nf} = \frac{(a-c-r)^2\left(\frac{(-2+\theta)(136+\theta(-28+\theta(-50+11\theta)))}{\left(-3+\theta^2\right)^2} + \frac{64(2+\theta)(136+\theta(20+\theta(50+\theta(7+3\theta))))}{(1+\theta)\left(-24-4\theta^2+\theta^4\right)^2}\right)}{256\beta}.$$

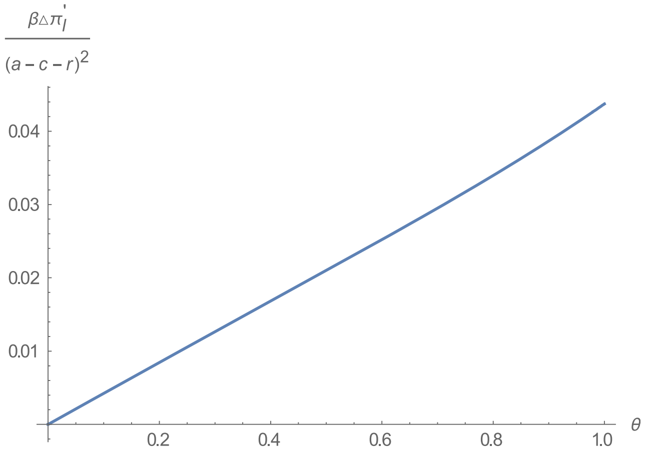

FIGURE F2 The relationship between $\frac{\beta \Delta \pi_I'}{(a-c-r)^2}$ and θ.

Figure F2, which plots $\frac{\beta \Delta \pi_I'}{(a-c-r)^2}$ for different values of θ, shows that the integrated firm's profit is higher under Bertrand competition compared to Cournot competition for $\theta \in (0,1)$.

(ii) We get

$$\Delta \pi_{NI}' = \widehat{\pi}_{NI}^{b,c,nf} - \widehat{\pi}_{NI}^{c,c,nf} = \frac{(a-c-r)^2 \left(\frac{(4-3\theta)^2}{\left(3-\theta^2\right)^2} - \frac{16(-1+\theta)(4+\theta)^2\left(2+\theta^2\right)^2}{(1+\theta)\left(24+4\theta^2-\theta^4\right)^2} \right)}{64\beta}.$$

Figure F3, which plots $\frac{\beta \Delta \pi_{NI}'}{(a-c-r)^2}$ for different values of θ, shows that the non-integrated firm's profit is higher under Bertrand competition compared to Cournot competition for $\theta < 0.726$ (approx.).

(iii) We get

$$\Delta \pi' = \left(\widehat{\pi}_I^{b,c,nf} + \widehat{\pi}_{NI}^{b,c,nf} \right) - \left(\widehat{\pi}_I^{c,c,nf} + \widehat{\pi}_{NI}^{c,c,nf} \right)$$

$$= \frac{(a-c-r)^2}{256\beta} \left(\frac{-336+\theta(288+(6-\theta)\theta(6-11\theta))}{\left(3-\theta^2\right)^2} + \frac{64\left(336+\theta\left(144+(2-\theta)\theta(3+\theta)\left(26+\theta(3+\theta)^2\right)\right)\right)}{(1+\theta)\left(24+4\theta^2-\theta^4\right)^2} \right).$$

Figure F4, which plots $\frac{\beta \Delta \pi'}{(a-c-r)^2}$ for different values of θ, shows that the industry profit is higher under Bertrand than under Cournot competition for $\theta \in (0,1)$.

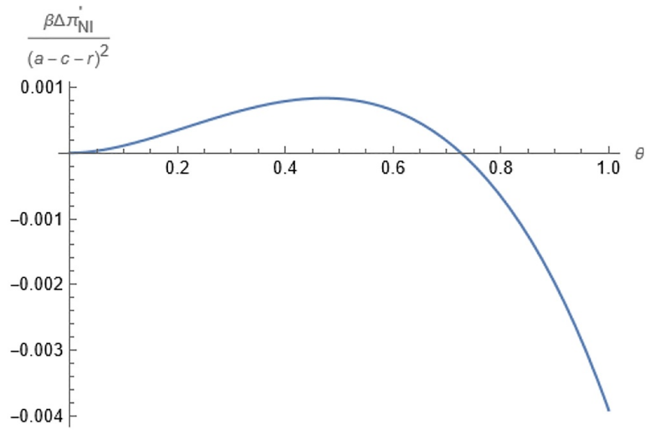

FIGURE F3 The relationship between $\frac{\beta \Delta \pi_{NI}'}{(a-c-r)^2}$ and θ.

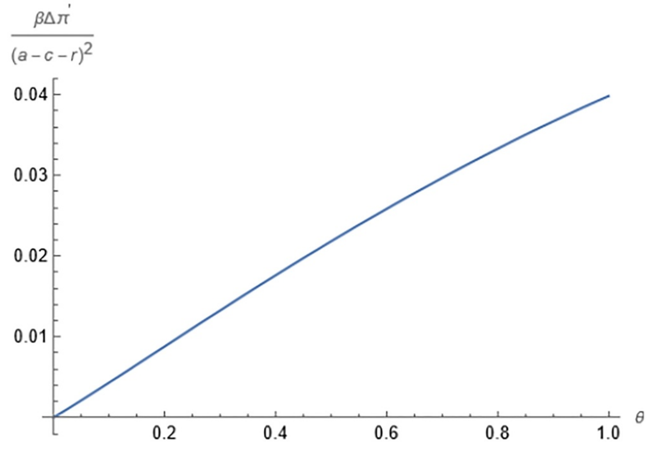

FIGURE F4 The relationship between $\frac{\beta \Delta \pi'}{(a-c-r)^2}$ and θ.

(iv) We get

$$\Delta CS' = CS^{b,c,nf} - CS^{c,c,nf}$$
$$= \frac{(a-c-r)^2}{512\beta}\left(\frac{-208+\theta^2(180-\theta(40+13\theta))}{\left(3-\theta^2\right)^2} + \frac{64(208+\theta(112+\theta(156+\theta(108+\theta(37+\theta(23+\theta))))))}{(1+\theta)\left(24+4\theta^2-\theta^4\right)^2}\right).$$

Figure F5, which plots $\frac{\beta \Delta CS'}{(a-c-r)^2}$ for different values of θ, shows that the consumer surplus is higher under Bertrand competition than under Cournot competition for $\theta > \theta^{***} = 0.547$ (approx.).

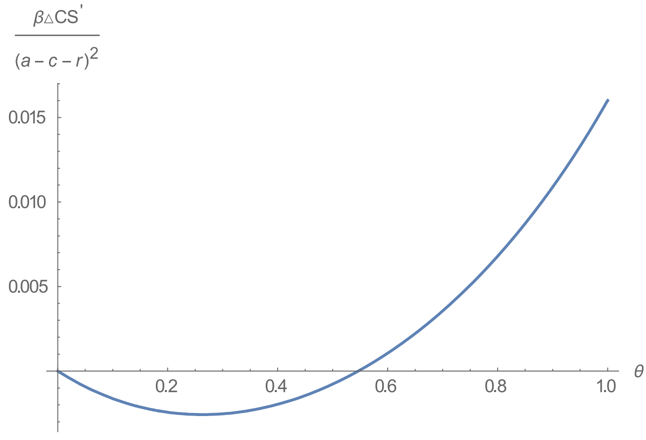

FIGURE F5 The relationship between $\frac{\beta\Delta CS'}{(a-c-r)^2}$ and θ.

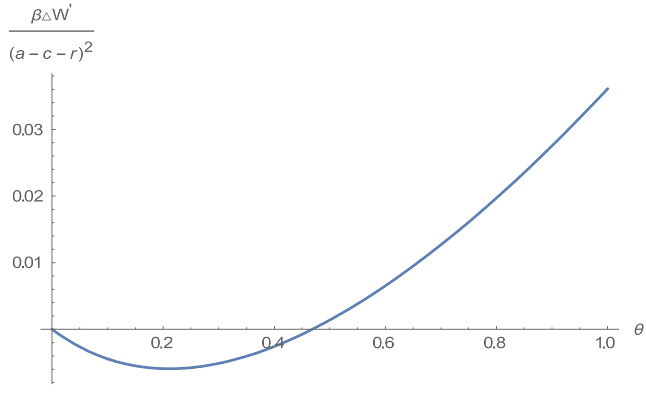

FIGURE F6 The relationship between $\frac{\beta\Delta W'}{(a-c-r)^2}$ and θ.

(v) We get

$$\Delta W' = W^{b,c,nf} - W^{c,c,nf}$$
$$= \frac{(a-c-r)^2}{512\beta}\left(\frac{-1712+\theta(960-\theta(556-\theta(280+19\theta)))}{(3-\theta^2)^2} + \frac{64(1712+\theta(464+\theta(836+\theta(276-\theta(5-\theta(1-4\theta(8+3\theta)))))))}{(1+\theta)\left(24+4\theta^2-\theta^4\right)^2}\right).$$

Figure F6, which plots $\frac{\beta\Delta W'}{(a-c-r)^2}$ for different values of θ, shows that the welfare is higher under Bertrand competition than under Cournot competition for $\theta > \theta^{****} = 0.469$ (approx.).