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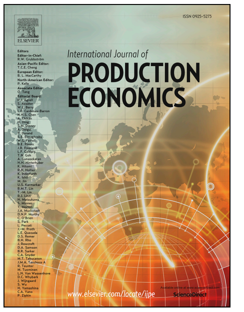

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Strategic Incentives for Complementary Producers to Innovate for Efficiency and Support Sustainability

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ABSTRACT

Process innovation that increases operational efficiency through a step change improvement in resource utilisation and waste reduction can help boost manufacturing profitability but also offer broader social and environmental benefits. Business owners, though, might be reluctant to make investments in process innovation unless they serve a pure profit motive. While not guided by altruistic intentions, the owners might nonetheless see a strategic benefit in providing their managers with remuneration incentives supported by public commitments to increase innovation effort for more efficient, lean and sustainable operations. We model such a possibility amongst producers controlling the supply of essential complementary components that go into the assembly of competitively produced composite finished goods. We demonstrate the ruinous effect of independent strategic delegation to managers of powerful complementary producers. Instead, collaboration amongst the owners of the complementary producers to establish common managerial incentives can increase innovative effort to raise efficiency that benefits the whole industry supply chain, end consumers, and social welfare. Government-backed voluntary agreements with sector-wide commitments may be helpful in encouraging process innovation to support lean supply chains and sustainability.

Key Words: Innovation; Efficiency; Sustainability; Incentives; Complements; Collaboration.

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1. Introduction

Process innovation that improves efficiency can help raise profitability but also provide wider societal benefits. Business owners, employees, consumers and the environment can all potentially share in the benefits from innovation that increases operational efficiency, raises resource utilisation, cuts waste, and lowers costs (Florida 1996; King and Lennox 2001; Piercy and Rich 2015). Thus, we might expect firms to be very strongly motivated to pursue process innovation for the advantages conferred on their own organisation through improved efficiency and competitiveness, but also encouraged by the magnitude of the broader benefits afforded to external stakeholders and society at large.

Nevertheless, all of this assumes that firms actually want and are prepared to pay for improved efficiency, which can require substantial investment and effort in process innovation. Business owners will obviously be deterred from undertaking such investments if the unit cost savings generated are not sufficient to cover the upfront investment expenditure. Yet, within a supply chain context, business owners might have other considerations that deter them as well. In particular, the mutual interdependence amongst firms in a supply chain means that an innovating firm might not fully appropriate the rewards from its own investment, as other parties can benefit as well. Specifically, the whole supply chain stands to gain from reduced costs if these allow for lower final prices and increased demand and sales. This can give rise to a free-rider problem and coordination failure, where each firm leaves it to others in the supply chain to incur the investment to reduce costs. If all parties think the same way then no one will innovate, cost savings will not materialise, and industry and social benefits will be lost.

In practice, two aspects can mitigate this free-rider problem. First, competition can act as a driver for implementing process innovation, where own survival in avoiding displacement by a more efficient rival takes priority over concerns about free riding by other parties in the supply chain. Secondly, contractual solutions might be possible whereby beneficiaries share the costs and rewards of process innovation. In particular, a pair of trading parties successively linked in a supply chain might recognise that both stand to gain from their own and each other's efforts to reduce costs, so agree as part of their trading contract to share investment costs and/or revenues (Gilbert and Cvsa 2003; Iida 2012).

What happens, though, if there is no competitive threat and parties cannot contract with each other? This paper considers precisely this situation in a supply chain where the critical parties are (upstream) monopoly component suppliers that provide essential complementary inputs used by (downstream) perfectly competitive assemblers of a composite finished good.

For example, the essential components could be hardware (e.g. an Intel processor) and software (e.g. a Microsoft operating system) required in the competitive production of personal computers. Here, any investment that one component supplier makes to reduce its operating costs and pass on lower prices to boost demand provides a direct benefit to another complementary component supplier, which can simply raise its prices correspondingly to leave sales at their original level but gain profit via its increased unit margin. With both component suppliers thinking the same way then they will both underinvest in cost-reduction effort. Furthermore, secure in their monopoly positions then there will be no competitive spur for them to innovate. Moreover, since they do not trade directly with each other, but instead lie horizontally (i.e. side-by-side) at the same level in the supply chain, then they will not have trading contracts with each other upon which they could add in agreements on sharing costs and benefits from innovation. How then, in the absence of competition or formal contractual solutions, could they limit free-riding behaviour to minimise the underinvestment problem?

We address this question by modelling a supply chain situation featuring complementary monopoly to consider differences between independent (non-cooperative) behaviour and collaborative (cooperative) behaviour. We contrast outcomes resulting from profit maximising behaviour with outcomes resulting from the business owners giving their managers remuneration contracts that have an explicit element relating to the amount of cost-reduction achieved through process innovation. We demonstrate how independent strategic delegation can exacerbate underinvestment in innovation. Instead, we show how owners' collaboration to establish common incentives can help the complementors increase innovation and benefit the whole supply chain, end consumers, and raise social welfare. We draw on these findings to discuss how industry standards, voluntary agreements and self-regulation could work to support welfare-raising collaboration. In particular, we see an important role that government can play in encouraging sector-wide commitments to innovation-led efficiency that promote lean supply chains and sustainability, such as the UK government-sponsored Courtauld Commitments for the UK food industry (WRAP 2011; 2017; Quinn 2017). The central tenet is that innovation-led efficiency-enhancing approaches give rise to sustainability.

The paper is organised as follows. The next section relates the paper to the extant literature. Section 3 set outs the modelling framework and game structure. Section 4 examines the non-cooperative and cooperative outcomes for profit maximising behaviour. Section 5 shows how the outcomes change with independent and cooperative strategic delegation by business owners, either rewarding or penalising innovation effort by managers. Section 6 concludes with the implications for promoting efficiency, lean operations, and sustainability.

2. Related Literature

The model and analysis in the paper draws on three distinct and currently separate literatures covering strategic interdependence amongst complementary producers, strategic delegation models involving process innovation, and innovation-led efficiency linked to lean operations and sustainability.

The building block of our analysis is Cournot's (1838, Ch. IX) model of side-by-side market power examining the price-setting behaviour of two complementary monopolists (copper and zinc) selling all their output in fixed proportions to a competitive industry manufacturing a composite commodity (brass). This essentially represents the first formal model of a manufacturing business system (Dobson 2006). The model is relevant to an array of policy debates, notably property rights policy (Heller 2008) and patent policy (Spulber 2017), and applications like bundling (Nalebuff 2003). More generally, the Cournot model helps appreciate the tension facing complementary firms with non-aligned incentives for *cooperating* (to increase the pool of available profits) and *competing* (over the division of profits) (Brandenburger and Nalebuff 1996; Yoffie and Kwak 2006).

The second stream of literature directly relevant to our analysis concerns strategic delegation models where business owners incentivise and delegate decision-making authority to managers as a commitment device (Fershtman and Judd 1987; Sengul et al. 2012). In respect of strategic delegation to induce cost-reducing R&D, Zhang and Zhang (1997) and Kopel and Riegler (2006) employ a complex multi-stage game structure where managers' operational decisions are sequenced, with innovation outcomes undertaken and the level of success becoming common knowledge before output decisions are made. Both papers have managerial contracts based on a linear combination of profit and sales revenue, which, while common in the strategic delegation literature, do not directly incentivise innovation effort.

In contrast, our approach follows Overvest and Veldman (2008), Veldman et al. (2014), and Veldman and Gaalman (2015) who examine strategic delegation to promote cost-reducing innovation effort in Cournot oligopoly. Their approach has several attractions. First, their models use a straightforward two-stage game structure, where owners set managerial contracts in the first stage and then managers make operational decisions in the second stage, with strategic behaviour squarely focused on the managerial contracts. Secondly, the manager contracts take the simple and intuitive form of a linear combination of profit and innovation outcomes (measured by the extent of success in reducing unit costs). Thirdly, all the operational decisions are tactical choices, allowing for tractable analysis yielding with straightforward closed-form solutions that are easy to interpret.

However, our paper differs from theirs in several key respects. First, our focus is on perfect complements in a supply chain compared to theirs on perfect substitutes in a homogenous final goods oligopoly. Second, strategic interaction works in the opposite manner, where softening competition and colluding is about *raising* prices in oligopoly but *lowering* them in complementary monopoly. Third, firms compete in outputs in Cournot oligopoly but in prices in Cournot complementary monopoly. Fourth, while in both cases these variables are *strategic substitutes* (i.e. the best response functions slope downwards), the character of aggressive strategic behaviour through credible and visible commitments works in the opposite way. With Cournot oligopoly, strategic behaviour is about commitments that serve to raise the firm's own output while obliging its rival to contract its output, assisted by strategically *overinvesting* in cost-reducing innovation to raise productive efficiency. In contrast, with Cournot complementary monopoly, aggressive strategic behaviour is about raising own price but obliging the rival to lower its price, assisted by strategically *underinvesting* in cost-reducing innovation to lower productive efficiency. The difference in these effects will have an important part to play in our model. Fifth, a further more subtle difference arises from the way that cost reduction efforts enter the profit functions we examine because they come via raising the profit margin, so directly influence quantity choices but only indirectly influence price choices. The upshot is that Cournot complementary monopoly is not the perfect dual problem of Cournot oligopoly, as often thought, which has some further effects on the results.[1]

Additionally, there are two other relevant approaches in the strategic delegation literature involving R&D effort. First, Pal (2010) considers collusion and semi-collusion delegation in an oligopoly context, but with a sales weighted managerial objective function. Second, Bárcena-Ruiz and Garzón (2002), Pal (2012), and Poyago-Theotoky and Yong (2017) consider explicit pollution reduction objectives when emissions taxes are present, but also in the context of oligopoly rather than within a supply chain involving complementary producers.

In addition to this research using game-theoretic modelling, we draw on insights from the burgeoning literature on innovation-led efficiency linked to lean supply chains and sustainability (Garza-Reyes 2015; Piercy and Rich 2015). In particular, we see a role for voluntary agreements to overcome industry reluctance to invest in reducing waste and adopting lean operations while promoting sustainability (Dashwood 2014; WRAP 2011; 2017).

[1] Sonnenschein (1968) shows the duality between Cournot oligopoly and complementary monopoly, but assumes zero costs. As Amir and Gama (2013) demonstrate, the perfect duality breaks down once there are non-zero costs.

3. Model Set Up

A composite manufactured good (say, brass) is competitively produced and assembled using two components (say, copper and zinc) in fixed and equal (1:1) proportions each supplied by a monopolist, indexed by i, $j = 1, 2$, $i \neq j$. The components have no other use other than in the manufacture of the composite good. The unit costs of making the composite good are a linear sum of the two component unit prices, respectively p_1 and p_2, and constant unit assembly costs at a rate of k per unit. The composite good industry is perfectly competitive and the manufactured good is sold to consumers at combined unit cost, such that its price per unit, denoted by P, is the linear sum of the two component unit prices and the assembly unit cost, i.e. $P = p_1 + p_2 + k$. The composite good industry faces linear consumer demand, with indirect demand in the general linear form expressed as $P = a - bQ$, where a, $b > 0$ and Q is the total number of units sold, so that direct demand is $Q = (a - P)/b = (a - p_1 - p_2 - k)/b$.

The component monopolists each set a fixed per unit price, as a posted non-negotiable price which is visible to the whole industry and applies to all units supplied. They both produce to order by letting the composite industry determine the quantity required, respectively q_1 and q_2, for the given component unit prices.[2] With the composite good being made in equal proportions and with normalised units then $Q = q_1 = q_2$.

In producing and supplying their respective goods, each component monopolist faces constant unit costs, but the level, c_i, can be influenced by process innovation effort. However, investment costs for process innovation are high and with diminishing returns. Specifically, existing technology and processes provides a base level unit cost rate at $\bar{c}$ but then each component monopolist can implement process innovation which lowers unit cost by the amount $x_i\ (> 0)$, so $c_i = \bar{c} - x_i$, at the investment cost of $F_i = \gamma x_i^2/2$. The cost improvement parameter, γ, is common to both firms and reflects the degree of difficulty and expense in implementing process innovation, where we assume $\gamma \geq 2$, as sufficient to ensure non-negative prices in all considered cases (and where $\gamma < 1$ rules out all cases). The technology and processes that each component producer uses are unique to the production and supply of their own good, and very different from the other component, so there is no prospect of technical spillover. Thus, only through the producer's own process innovation investments can it lower its own operating costs.[3]

[2] The alternative of quantity competition results in the market collapsing with the firms setting zero output (Sonnenschein 1968; Dobson 1992).

[3] We are assuming here that innovation leading to cost reduction is deterministic in the sense that expenditure on innovation effort translates through to a certain cost saving, such as scaling-up tried-and-tested technology.

To reduce notation and without further loss of generality, we set the composite industry's marginal cost parameter and the base level cost parameter for the two component monopolists to zero, so respectively $k = 0$ and $\bar{c} = 0$. Regarding consumer demand for the composite good, we normalise market size and price sensitivity to unity, so then $a = 1$ and $b = 1$ and thus $Q = 1 - p_1 - p_2$. Thereby we focus attention on the component monopolists' decisions on their levels of unit cost reduction, x_1 and x_2, and their prices, p_1 and p_2, as the key decision variables that determine market outcomes for given realisations of the efficiency improvement parameter γ.

In respect of the timing of decisions, both cost reduction investments and prices are set simultaneously and are independently determined by the two component producers unless a cooperative agreement allows for coordinated joint determination. We view each component producer's simultaneous choice of innovation effort and price as fixed in anticipation of the subsequent demand from the composite good industry. Specifically, innovation requires upfront investment expenditure as an irreversible sunk cost made independently and unobserved by the other industry participants when making their own decisions.

We model innovation effort and prices as Nash equilibrium outcomes from a one shot game with all operational decisions made at the same time under complete information, so demand and cost structures are common knowledge. However, we allow for consideration of different objective functions for the component producers in this stage game. We start with the two ways in which Cournot originally conceived the complementary monopoly situation. First, as the base case, the two monopoly producers are independent profit maximisers. Second, the two monopoly producers make coordinated decisions to maximise their joint profits as if fused into a single combined monopolist. This second case is the benchmark case because in a single unified monopoly represents the highest level of achievable economic welfare in this industry setting (assuming that a regulator does not intervene to mandate perfectly competitive behaviour). The comparison of the two cases highlights the extent to which independent profit maximising behaviour harms welfare resulting from prices being set excessively high and cost reduction effort set unduly low compared to decisions based on joint profit maximisation.

Joint profit maximisation on the market decisions might be desirable but not achievable. For example, the respective business owners of the complementary monopolists might not be prepared to merge their businesses and market collusion might not be feasible in the absence of a mechanism to support a fully collusive agreement. If so, we consider how the owners might instead seek to shape the contracts of their managers in a way that provides for more favourable outcomes than the alternative arising from blunt independent profit maximising.

Specifically, we are interested to see what would be the effect of intentionally having managers focus on the extent of innovation effort for its own sake, alongside profit considerations. We model strategic delegation of this nature, with manager contracts determined in advance of operational decisions, as subgame perfect equilibrium outcomes in two situations to draw comparisons with the base and benchmark cases. First, we examine the two sets of business owners independently determining their respective manager contracts with the intention of satisfying their own profit maximising objectives. This is the standard approach in the literature on strategic delegation, but turns out to be even more harmful to societal welfare than the base case of independent profit maximising behaviour. Second, as an alternative means of strategic delegation, we consider joint determination of manager incentives through industrywide commitments supported by both sets of business owners.

4. Profit Maximising Outcomes

This section derives and compares the outcomes for the cases of independent and joint profit maximising behaviour. The respective set of outcomes will serve as useful yardsticks by which to make comparisons with the outcomes from the strategic delegation cases considered in the next section.

4.1 Independent profit maximising behaviour

As the base case, we consider the component producers simultaneously and independently determining their respective prices and innovation efforts to maximise their own profits. Using the above assumptions, the profit function for component monopolist *i* is

$$\pi_i = (p_i - c_i)Q - F_i = (p_i + x_i)(1 - p_i - p_j) - \gamma x_i^2/2 \tag{1}$$

Maximising profit with respect to cost-reduction effort and price levels, the necessary first-order conditions are

$$\frac{\partial \pi_i}{\partial x_i} = 1 - p_i - p_j - \gamma x_i = 0 \tag{2}$$

$$\frac{\partial \pi_i}{\partial p_i} = 1 - 2p_i - p_j - x_i = 0 \tag{3}$$

Solving the set of four first-order conditions shows, with $\gamma \geq 1$ necessary for non-negative prices, the Nash equilibrium outcomes (designated with the superscript *N*) for the amount of cost reduction achieved and the supply price chosen as respectively

$$x_i^N = \frac{1}{3\gamma - 2} \tag{4}$$

$$p_i^N = \frac{\gamma - 1}{3\gamma - 2} \tag{5}$$

We can note that the equilibrium innovation effort is decreasing in γ (i.e. $\partial x_i^N/\partial\gamma < 0$) as expected since the parameter captures the degree of difficulty and expense in implementing process innovation, but which also entails the equilibrium prices increasing in γ (i.e. $\partial p_i^N/\partial\gamma > 0$) as the monopolists pass on the higher innovation costs to the composite goods makers. However, their profitability suffers as innovation costs rise with the equilibrium unit mark-up, $p_i^N + x_i^N = \gamma/(3\gamma - 2)$, decreasing in γ. The direction of these effects will be common to all the cases we examine, but the magnitudes will be different for the different equilibrium outcomes.

Using (4) and (5), we can determine the remaining market outcomes in this case. For convenience, Table 1 (second column) summarises all these outcomes. These cover the quantity demanded, Q^N, the amount of investment that each monopolist makes on cost reduction, F_i^N, the profit each firm makes, π_i^N, the combined industry profits, $\Pi^N = \pi_1^N + \pi_2^N$, the total consumer surplus, CS^N, and the total economic welfare, W^N, as the sum of industry profits (i.e. producer surplus) and consumer surplus.

– Table 1 near here –

4.2 Joint Profit Maximising Behaviour

Following in the spirit of Cournot, we next examine the outcomes under joint profit maximisation, equivalent to the fusion of the two monopolists into a single merged entity. The joint profit of the two component monopolists from the perspective of monopolist *i* is

$$\begin{aligned}\Pi = \pi_i + \pi_j &= (p_i + p_j - c_i - c_j)Q - F_i - F_j \\ &= (p_i + p_j + x_i + x_j)(1 - p_i - p_j) - \gamma(x_i^2 + x_j^2)/2\end{aligned} \tag{6}$$

Maximising the joint profit with respect to the two innovation-induced cost reduction levels and two price levels, the necessary first-order conditions are

$$\frac{\partial\Pi}{\partial x_i} = 1 - p_i - p_j - \gamma x_i = 0 \tag{7}$$

$$\frac{\partial\Pi}{\partial p_i} = 1 - 2p_i - 2p_j - x_i - x_j = 0 \tag{8}$$

Solving the set of four first-order conditions and assuming a symmetric solution on prices (as a natural default position given the monopolists' symmetry and requiring $\gamma \geq 2$ to be non-negative) reveals the merger-equivalent equilibrium choices and resulting market outcomes, which we designate with superscript *M* and report in Table 1 (third column).

Contrasting the choices and resulting market outcomes from independent profit maximising behaviour (from Table 1 second column) and joint profit maximising behaviour (from Table 1 third column) allows us to establish the following proposition:

Proposition 1. *Joint rather than independent profit maximising behaviour provides for higher industry profits, increased consumer surplus, and improved efficiency arising from greater investment in process innovation.*

Proof. Direct comparisons of the equilibrium outcomes show respectively that $\Pi^M > \Pi^N$, $CS^M > CS^N$, $x_i^M > x_i^M$, and $F_i^M > F_i^N$. (See Appendix Table A1 for proofs to all propositions).

This finding extends Cournot's (1838, p.103) insight that "the composite commodity will always be made more expensive, by reason of separation of interests than by reason of the fusion of monopolies." Independent profit maximisation results in negative externality effects, where each producer in setting a high price does not consider the harm on demand for the other producer, leading to inefficiently high prices. This so-called "Cournot effect" is the horizontal equivalent of "double marginalisation" in a successive monopoly vertical supply chain, albeit with simultaneous rather than sequential price mark-ups (Nalebuff 2003). However, when the two complementary producers collude, they internalise these effects and lower prices with a bundled offer that benefits consumers, unlike in oligopoly where collusion amongst competing producers results in higher prices.

Thus, the strategic interaction effect of independent profit maximisation is that component prices are too high resulting in lower sales of the composite good. However, in our context, this has an important knock-on consequence for the extent of process innovation with cost-reduction effort directly linked to the equilibrium sales level. This is evident from the first-order condition in respect of the choice of innovative effort which in both cases is exactly the same with $\partial\pi_i/\partial x_i = \partial\Pi/\partial x_i = 1 - p_i - p_j - \gamma x_i = 0$, which implies that $x_i = Q/\gamma$ since $Q = 1 - p_i - p_j$. Accordingly, with lower equilibrium sales resulting from inefficiently high component prices then there is also reduced innovative effort compared to when prices are jointly coordinated. Thus, it is not just that independent profit maximisation lowers profits (which jointly harms the firms), and results in an excessively high price for the composite good (which harms consumers), but that productive efficiency is less than it would be under joint profit maximisation.

Proposition 1 shows that the respective owners of the component producers have a vested interest in merging the two monopolists to release the trapped added value and thereby enhance the company valuations. Moreover, if there were no risk of entry or foreseeable change in the structure of the market then presumably competition authorities would allow a merger. In practice, though, authorities have been reluctant to rely on the *Cournot effect* argument in complementary producer mergers especially if these might lock-in market power. For example, the European Commission blocked the *GE/Honeywell* merger in 2001 with concerns about enhanced bundling power (Choi 2008; Spulber 2017). There might also be other practical reasons why the two businesses might not be able to merge, such as ownership restrictions (e.g. on foreign ownership) or unduly complex and/or fragmented ownership structures which make share trading difficult (Heller 2008).

If merger were not possible or palatable to the owners then the alternative for obtaining joint profit maximisation would be through collusion. Again, competition authorities might not be averse to a horizontal pricing agreement between complementors if there were likely to be material benefits for consumers. Nevertheless, there might be two key practical reasons that make coordination difficult. First, each monopolist will have a private incentive to deviate from any collusive agreement to keep prices low, because it can gain additional profit by surreptitiously raising its own price. In the present context of a one shot game there is no threat of retaliation to sustain collusion (such as there might be through an infinitely repeated game), and so any agreement might unravel, leaving the two monopolists to end up with the Nash equilibrium outcomes from independent profit maximisation. Secondly, both parties would need to agree the individual price levels, as prices here are only determined in aggregate (i.e. the combination of the two prices passed on to the composite good makers). The default, as we have assumed above given their symmetry, is that they agree to set the same prices so have an equal share of joint profit. However, in practice, the two monopolists might not be so accommodating in their negotiations and they might each demand more than an equal share, resulting in disagreement and a failure to conclude a collusive arrangement.

Consequently, if merger or collusion is not feasible then we are left to consider whether the firms might be able to undertake some form of prior strategic action to favourably influence these operational decisions. To this end, we examine next how the business owners might influence the outcomes through designing remuneration packages to motivate their managers to take account of profit along with a specific weighting on resource efficiency targets.

5. Strategic Delegation Outcomes

This section extends the analysis to a two-stage game. In the first stage, the two sets of business owners simultaneously determine an incentive contract for their respective manager based on a linear combination of profits and cost-reduction effort, which they might be inclined to make publicly visible if this aids their CSR credentials (Kolk and Perego 2014; Maas and Rosendaal 2015; Glass Lewis 2016). In the second stage, being aware of each other's contracts, the two managers unilaterally decide on their price and targeted cost-reduction levels.

We begin with the case of independent (non-cooperative) strategic delegation where each set of business owners separately decides on the incentive contracts for their own manager. We then consider the case of collaborative (cooperative) strategic delegation where both set of business owners set the same structure of incentive contracts. With complete information, where there is clarity and understanding in the market about the managers' contracts, we derive and then compare the subgame perfect equilibrium outcomes for these two cases.

5.1 Independent Strategic Delegation

Following Overvest and Veldman (2008), Veldman et al. (2014), and Veldman and Gaalman (2015), each set of owners provides their respective manager with a contract that depends on a linear combination of a profit and process innovation bonus with the total compensation expressed as the salary function $S_i = \pi_i + \lambda_i x_i$, where λ_i is the monetary return per unit of realised operational cost reductions.[4] Accordingly, λ_i represents the weight the owners attach to the firm's level of innovative effort, so the higher (respectively, lower) is this strategic remuneration variable then the more (respectively, less) the manager will direct the firm's resources towards innovation. We allow the owners to determine the sign and magnitude of this variable, recognising that a positive value provides extra encouragement to innovative effort and lowering operational costs while a negative value discourages innovative effort with a view to leaving operational costs high while saving on investment expenditure.

We start by considering independent (non-cooperative) choices made by the respective owners as the weight they attach to their respective firm's level of cost-reduction effort. The game structure now changes into a two-stage game. Firstly, each set of owners simultaneously

[4] Following Fershtman and Judd (1987), the actual payment to the manager takes the form $A_i + B_i S_i$, with $A_i > 0$ and $B_i > 0$ as exogenously specified constants. Maximising this payment function is equivalent to maximising S_i for a risk-neutral manager if the only control variables are the price and innovation-based cost-reduction levels.

determines their respective value for λ_i. Then, the two managers simultaneously choose price and targeted cost-reduction levels with their intention to maximise their own respective compensation levels. With complete and perfect information, the appropriate solution concept is the subgame perfect Nash equilibrium (SPNE), solved by backward induction.

In the second stage, both managers choose process innovation and price levels to maximise their respective salary functions:

$$S_i = (p_i - c_i)Q - F_i + \lambda_i x_i = (p_i + x_i)(1 - p_i - p_j) - \gamma x_i^2/2 + \lambda_i x_i \tag{9}$$

The necessary first-order conditions are

$$\frac{\partial S_i}{\partial x_i} = 1 - p_i - p_j - \gamma x_i + \lambda_i = 0 \tag{10}$$

$$\frac{\partial S_i}{\partial p_i} = 1 - 2p_i - p_j - x_i = 0 \tag{11}$$

Note that the incentive structure works directly on the innovation effort choice but not on the price choice, since $\partial S_i/\partial p_i = \partial \pi_i/\partial p_i$, and so any impact on price is only indirectly through how the cost-reduction effort level affects the firm's marginal cost. Clearly, $\partial S_i/\partial x_i > (<)\, \partial \pi_i/\partial x_i$ for $\lambda_i > (<)\, 0$. Solving the set of four first-order conditions, with $\gamma \geq 1$ necessary for non-negative prices, shows the second-stage equilibrium choices to be

$$x_i(\lambda_i, \lambda_j) = \frac{\gamma + (3\gamma - 1)\lambda_i + \lambda_j}{\gamma(3\gamma - 2)} \tag{12}$$

$$p_i(\lambda_i, \lambda_j) = \frac{(\gamma - 1)(\gamma + \lambda_j) - (2\gamma - 1)\lambda_i}{\gamma(3\gamma - 2)} \tag{13}$$

The effect of λ_i and λ_j are positive on the targeted cost-reduction level selected by firm *i*'s manager, but the strength of the cross effect is very small compared to the influence of the own effect. In contrast, λ_i and λ_j have opposing effects on the price level chosen by the manager, where the own effect is negative while the cross effect is positive but weaker.

Anticipating these outcomes chosen by the managers, each firm's owners determine the innovation effort weighting parameter λ_i in the first stage using these second-stage outcomes when maximising the firm's profit function:

$$\begin{aligned} \pi_i(\lambda_i, \lambda_j) &= (p_i - c_i)Q - F_i = (p_i + x_i)(1 - p_i - p_j) - \gamma {x_i}^2/2 \\ &= \frac{(2\gamma - 1)(\gamma + \lambda_j)^2 - 2(\gamma - 1)(\gamma + \lambda_j)\lambda_i - (9\gamma^2 - 8\gamma + 1){\lambda_i}^2}{2\gamma(3\gamma - 2)^2} \end{aligned} \tag{14}$$

Optimising with respect to λ_i and rearranging the first-order condition provides the following best response function which is decreasing in λ_j:

$$\lambda_i(\lambda_j) = -\frac{(\gamma - 1)(\gamma + \lambda_j)}{9\gamma^2 - 8\gamma + 1} \quad (15)$$

Solving for the equilibrium values, the owners of each firm set their manager the following innovation incentive under "independent delegation" (designated with superscript *ID*):

$$\lambda_i^{ID} = -\frac{\gamma - 1}{9\gamma - 7} < 0 \quad (16)$$

Observing the symmetry, with $\lambda_1^{ID} = \lambda_2^{ID}$, and substituting this equilibrium value back into the second stage outcomes, (12) and (13), reveals the subgame perfect equilibrium outcomes under independent delegation which are collected and reported in Table 1 (penultimate column).

Clearly, far from encouraging managers to pursue efficiency-enhancing innovation, the owners instead *discourage* innovative effort by penalising managers in their compensation packages, by assigning a negative value for λ_i. Independent strategic delegation by the owners thereby works to curtail investment and encourage inefficient production with high unit costs. In essence, owners incentivise managers to adopt wasteful-but-cheap technology and methods rather than efficient-but-expensive technology and methods. The reason is that committing to a raised unit cost in turn commits the producer to a higher unit price and puts pressure on the complementary producer to correspondingly lower its price and so not reduce final goods demand. However, because both complementary producers act in the same self-interested way then the result is both firms' prices and margins increase but final goods demand falls to such an extent that everyone – owners, consumers and society – are worse off compared to the absence of strategic delegation by both firms, as summarised by the following proposition:

Proposition 2. *Independent strategic delegation by owners penalises cost-reducing effort and results in managers choosing lower process innovation effort, higher prices and less output compared to decisions based on independent profit maximising behaviour to the extent that industry profits, consumer surplus and societal welfare are all lower.*

Proof. Direct comparisons of the equilibrium outcomes show respectively that $x_i^{ID} < x_i^M$, $F_i^{ID} < F_i^M$, $p_i^{ID} > p_i^M$, $Q^{ID} < Q^N$, $\Pi^{ID} < \Pi^N$, $CS^{ID} < CS^N$, and $W^{ID} < W^N$. (See Table A1).

Somewhat analogous to Gilbert and Cvsa (2003), who examine investment in a successive (vertical) monopoly situation, there are two forces working in tandem driving underinvestment in this non-cooperative setting. First, both sets of owners do not take into account the positive externality effect of innovative effort for each other, where lower costs translate into lower component prices and raised demand that benefits the whole supply chain. Second, there is a mutual hold-up effect with each set of owners wanting the other set to entice their manager to increase innovative effort, which then allows them, in a free-riding sense, to reduce their own firm's innovation effort, and take advantage to raise price by being more inefficient. With both sets of owners thinking the same way, then they both commit to penalising their respective managers for undertaking innovative effort. Thereby, both firms undertake even less innovation than they would with independent profit maximising behaviour.

This finding is directly opposite to the results in Cournot oligopoly, where Overvest and Veldman (2008), Veldman et al. (2014), and Veldman and Gaalman (2015) show that owners set positive innovation bonuses to encourage their managers to reduce costs. However, both cases have in common a prisoner's dilemma structure, where independent delegation is individually a dominant strategic choice but not in the firms' joint interests.[5] Yet, the welfare outcomes are starkly different. In Cournot oligopoly, the positive innovation bonus induces the managers to raise efficiency and output, which lowers industry profits but raises consumer surplus and social welfare. In our complementary monopoly case, though, the outcome is a triple loss where industry profits, consumer surplus and social welfare are all lower.

5.2 Collaborative Strategic Delegation

As a contrast to independent delegation, we consider collaborative delegation. Here, the two sets of owners cooperate in determining how much they reward their managers for cost-reduction effort but still have their respective managers independently (i.e. non-cooperatively) determine the actual amount of innovation and corresponding price levels.

While perhaps not easy to coordinate, we envisage that joint determination and a shared focus on a common incentive level to promote cost reduction might come about through different possible drivers. First, collaborative strategic delegation could represent a form of "semi-collusion", where the two sets of owners by their own volition recognise their mutual interdependence and coordinate on a common incentive structure to motivate and reward their managers. For example, the owners might jointly make publicly pledged CSR and sustainability commitments promoting waste reduction and improving resource efficiency, but then leave their managers to make independent non-cooperative operational decisions. Secondly, a coordinated approach on managerial incentives might arise through regulatory obligation or pressure. For example, the government could mandate or coordinate a

[5] By considering the asymmetric case where $\lambda_j = 0$, it is easy to show that each set of owners always prefers to have their manager *not* maximising profit regardless of whether the other firm is or is not profit maximising.

sustainability focus with accountability and targets for reducing waste and lessening harm to the environment through promoting efficiency-enhancing innovation, made more credible when backed up by the threat of taxes or other penalties if targets are not met. Moreover, such government involvement would have clear public support when it clearly benefits both consumers and the environment. Thirdly, even without governmental involvement, pressure to coordinate on common sustainability objectives might arise from within the supply chain. In particular, the downstream assembly industry has an interest to ensure the monopoly component suppliers do not underinvest in cost-reduction effort, since higher prices will lead to less demand, shrinking sales, and displacement of marginal assembly firms forced out of business. For example, as their customers, the downstream firms might lobby for the component suppliers to adopt a shared purpose with common resource efficiency and waste reduction targets, then formalised as industrywide CSR commitments.

Thus, by the medium of public joint commitments, credibly related to sustainability obligations, we consider the owners of the two complementary suppliers making a first-stage choice to set a common parameter λ with the objective of maximising combined industry profits. The second-stage outcomes, where the managers make independent choices over the innovation and price levels are the same as (12) and (13) but with the restriction that $\lambda_i = \lambda_j = \lambda$, so simplify to

$$x_i(\lambda) = \frac{1 + 3\lambda}{3\gamma - 2} \tag{17}$$

$$p_i(\lambda) = \frac{\gamma - 1 - \lambda}{3\gamma - 2} \tag{18}$$

Anticipating these levels, the owners in the first stage coordinate on setting λ to maximise combined sector profits:

$$\begin{aligned} \Pi(\lambda) &= (p_1 + p_2 + x_1 + x_2)(1 - p_1 - p_2) - \gamma(x_1^2 + x_2^2)/2 \\ &= \frac{\gamma(2\gamma - 1) + 2\gamma\lambda - (9\gamma - 8)\lambda^2}{2(3\gamma - 2)^2} \end{aligned} \tag{19}$$

Taking the first order condition where $\partial\Pi/\partial\lambda = 0$ and solving reveals that the owners set the following pro-innovation incentive to their respective managers under “collaborative delegation” (designated with superscript *CD*):

$$\lambda^{CD} = \frac{\gamma}{9\gamma - 8} > 0 \tag{20}$$

Substituting this equilibrium value back into the second stage outcomes determines the subgame perfect equilibrium outcomes under collaborative delegation, as reported in Table 1 (final column), where the necessary requirement for non-negative prices is $\gamma \geq 4/3$.

By setting a common incentive and reward for cost-reduction effort, the two sets of owners internalise the positive externality effect of innovative effort for each other, where dual cost reduction allows for lowers prices, higher quantity and increased combined profits. In addition, by coordinating on the common innovation incentive, the owners help alleviate the mutual hold-up effect by jointly pushing their respective managers to match each other in being more efficient, rather than seeking to free ride on the other's innovation effort and behaving opportunistically to raise price from being more inefficient. The upshot is more innovation effort than under either independent strategic delegation or independent profit maximisation, and a second-best outcome if full cooperation or merger is not feasible:

Proposition 3. *Collaborative strategic delegation rewards cost reduction and results in managers choosing more process innovation effort, lower prices and more output compared to decisions arising under independent profit maximising behaviour or independent strategic delegation, and so represents a second-best outcome compared to full coordination or merger.*

Proof. Direct comparisons of the equilibrium outcomes show respectively that $x_i^M > x_i^{CD} > x_i^N > x_i^{ID}$, $F_i^M > F_i^{CD} > F_i^N > F_i^{ID}$, $p_i^M < p_i^{CD} < p_i^N < p_i^{ID}$, $Q^M > Q^{CD} > Q^N > Q^{ID}$, $\Pi^M > \Pi^{CD} > \Pi^N > \Pi^{ID}$, $CS^M > CS^{CD} > CS^N > CS^{ID}$, and $W^M > W^{CD} > W^N > W^{ID}$. (Table A1).

Figure 1 illustrates this result, showing the best response functions in prices and equilibrium outcomes under each of the four scenarios. For independently set operational decisions, the best response functions takes the form $R_i(p_j) = [(1 - p_j)(\gamma - 1) - \lambda_i]/(2\gamma - 1)$. Compared to the best response functions under independent profit maximisation (shown as R_i^N and where $\lambda_i = 0$), independent strategic delegation leads to underinvestment in cost-reduction effort which shifts out the price response functions (shown as R_i^{ID} and where $\lambda_i = \lambda_i^{ID} < 0$). This is because prices for complementary monopolists are *strategic substitutes* (i.e. downward sloping best response functions) and investment in innovative effort makes the firm soft by allowing the other firm to take advantage and maintain a higher price and boost its own profit. Thus, the firms adopt a "lean and hungry look" strategy, in the terminology of Fudenberg and Tirole (1984). In contrast, collaborative delegation raises innovation and shifts in the best response functions (shown as R_i^{CD} and where $\lambda_i = \lambda_i^{CD} > 0$), but the equilibrium price is still higher than under full coordination or merger (where R^M represents the contract curve and the set of Pareto efficient outcomes where $p_1 + p_2 = (\gamma - 2)/(2(\gamma - 1))$.

– Figure 1 near here –

If semi-collusion is feasible then it begs the question why full cooperation might not be feasible. As explained in section 4.2, collusion on pricing might be difficult when the two firms have to agree on their exact prices levels and each has an incentive for hidden action to deviate and surreptitiously raise its price. The same private incentive to deviate exists on an agreement between both sets of owners on the common incentive they set their managers for undertaking process innovation. However, joint public declarations reduce the scope for reneging, especially if there is reputational harm or some other implicit penalty. In particular, owners might be concerned about a government or public backlash if they fail to support resource efficiency for the sake of sustainability. In the same vein, requirements for managers to formally report on CSR (e.g. in line with EC Directive 2014/95/EU or ISO 26000 Guidance Standard on Social Responsibility) might also help support industrywide commitments.

In this light, we might see genuine attempts, beyond greenwash, for industries and supply chains to innovate with clear joint targets on reducing costs and wastage as possible commitment mechanisms. This might especially apply to industries viewed as environmentally unfriendly, such as mining (Dashwood 2014), or where waste is high in the public conscience, like food waste. With shared objectives and the ability to monitor each other, firms might avoid the temptation to deviate and free ride on the innovation effort of other parties in the supply chain to reduce waste and increase efficiency. This can help avoid a ruinous prisoner's dilemma situation where underinvestment in innovation harms industry profits, consumer welfare, and the environment. Thus, a clear role exists for industry standards, voluntary agreements and self-regulation to work together to overcome opportunism and support welfare-raising collaboration that benefits the triple bottom line (Haufler 2001; King and Lenox 2000). Through this means, innovation-led efficiency enhancing approaches can support sustainability.

6. Conclusion

Our analysis calls for collaborative solutions within supply chains to encourage investment in process innovation. We see the best prospect for this being in respect of process innovation that promotes sustainability, with industry and societal interests aligned and having the support of government and the public concerned about environmental harm and resource depletion. Examples exist of such sector-wide collaboration. For instance, the Courtauld

Commitment 2025 is a voluntary agreement that commits the UK food industry to collaborative action in cutting the resources needed to provide food and drink by one-fifth over ten years (WRAP 2017). The broader aim is to achieve UN Sustainable Development Goal 12.3 by 2030 in halving food waste. The agreement includes collaborative effort on whole chain resource efficiency and builds on previous successes in reducing food and packaging waste across multiple supply chains. The emphasis is on innovating through lean operations as the most effective way to reduce costs, food waste, and greenhouse gas emissions (WRAP 2011). The UK government will, if necessary, pressure reticent producers to participate (Quinn 2017).

Finally, we recognise that our parsimonious model clearly understates the complexity of manufacturing supply chains, but our key findings appear robust to a number of extensions. First, we could follow Veldman et al. (2014) and allow for stochastic innovation, which effectively raises γ as the probability of success declines, serving to provide an even stronger need for collaboration on innovation effort. Second, we could allow for n (> 2) complementary monopolists, in a similar vein to Overvest and Veldman (2008) who consider an n-firm Cournot oligopoly. As n increases, we expect the cumulative problem of underinvestment and excessive pricing to become even more acute, so again a greater need for collaboration on innovation effort. Moreover, we cannot rely on mergers fixing the problem since, as Gaudet and Salant (1992) demonstrate, incentives for endogenous mergers breakdown when there are more than two complementary monopolists. Thirdly, following Bergstrom (1978), we could allow for variable proportions rather than fixed proportions technology in the assembly industry. Even so, as long as the component producers maintain a complementary demand relationship then we would expect the same pricing and innovative externality effects to prevail and so a need for collaborative strategic delegation. Fourthly, the downstream industry could also be a monopoly and, while vertically coordinated price bargaining might resolve the pricing externality problem, there could still be value in committing to coordinated innovation effort to overcome free-riding incentives on process innovation investments. Future research, though, might wish to consider innovation incentives across overlapping or competing supply chains.

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Appendix. Proofs for Propositions 1-3

– Table A1 near here –

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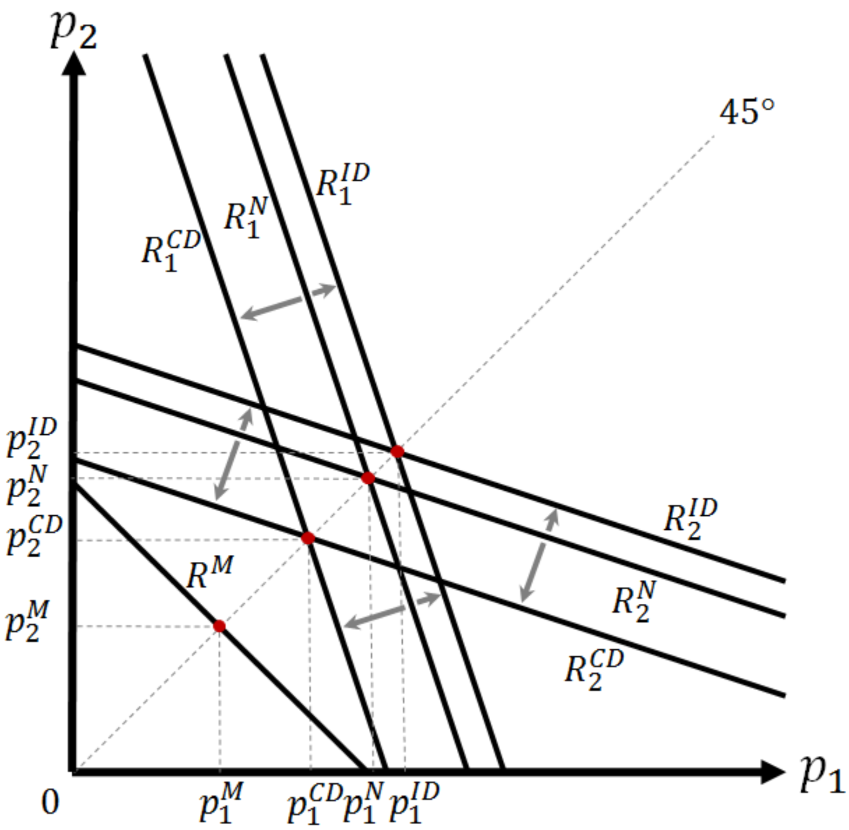
Table 1. Complementary Monopoly Equilibrium Outcomes

Equilibrium Outcomes	**Independent Profit Maximisation** (Nash Equilibrium Outcomes)	**Joint Profit Maximisation** (Collusion Equivalent to Merged Monopoly)	**Independent Strategic Delegation** (Non-Cooperative Outcomes)	**Collaborative Strategic Delegation** (Semi-Collusion Outcomes)
Unit Cost Saving	$x_i^N = \frac{1}{3\gamma - 2}$	$x_i^M = \frac{1}{2(\gamma - 1)}$	$x_i^{ID} = \frac{2}{9\gamma - 7}$	$x_i^{CD} = \frac{4}{9\gamma - 8}$
Supplier Price	$p_i^N = \frac{\gamma - 1}{3\gamma - 2}$	$p_i^M = \frac{\gamma - 2}{4(\gamma - 1)}$	$p_i^{ID} = \frac{3(\gamma - 1)}{9\gamma - 7}$	$p_i^{CD} = \frac{3\gamma - 4}{9\gamma - 8}$
Output Quantity	$Q^N = \frac{\gamma}{3\gamma - 2}$	$Q^M = \frac{\gamma}{2(\gamma - 1)}$	$Q^{ID} = \frac{3\gamma - 1}{9\gamma - 7}$	$Q^{CD} = \frac{3\gamma}{9\gamma - 8}$
Innovation Expenditure	$F_i^N = \frac{\gamma}{2(3\gamma - 2)^2}$	$F_i^M = \frac{\gamma}{8(\gamma - 1)^2}$	$F_i^{ID} = \frac{2\gamma}{(9\gamma - 7)^2}$	$F_i^{CD} = \frac{8\gamma}{(9\gamma - 8)^2}$
Supplier Profit	$\pi_i^N = \frac{\gamma(2\gamma - 1)}{2(3\gamma - 2)^2}$	$\pi_i^M = \frac{\gamma}{8(\gamma - 1)}$	$\pi_i^{ID} = \frac{9\gamma^2 - 8\gamma + 1}{(9\gamma - 7)^2}$	$\pi_i^{CD} = \frac{\gamma}{9\gamma - 8}$
Total Industry Profit	$\Pi^N = \frac{\gamma(2\gamma - 1)}{(3\gamma - 2)^2}$	$\Pi^M = \frac{\gamma}{4(\gamma - 1)}$	$\Pi^{ID} = \frac{2(9\gamma^2 - 8\gamma + 1)}{(9\gamma - 7)^2}$	$\Pi^{CD} = \frac{2\gamma}{9\gamma - 8}$
Consumer Surplus	$CS^N = \frac{\gamma^2}{2(3\gamma - 2)^2}$	$CS^M = \frac{\gamma^2}{8(\gamma - 1)^2}$	$CS^{ID} = \frac{(3\gamma - 1)^2}{2(9\gamma - 7)^2}$	$CS^{CD} = \frac{9\gamma^2}{2(9\gamma - 8)^2}$
Total Welfare	$W^N = \frac{\gamma(5\gamma - 2)}{2(3\gamma - 2)^2}$	$W^M = \frac{\gamma(3\gamma - 2)}{2(\gamma - 1)^2}$	$W^{ID} = \frac{45\gamma^2 - 38\gamma + 5}{2(9\gamma - 7)^2}$	$W^{CD} = \frac{\gamma(45\gamma - 32)}{2(9\gamma - 8)^2}$

Figure 1. Best Response Functions and Equilibrium Prices



Appendix. Proofs for Propositions 1-3

Table A1. Equilibrium Outcome Comparisons

Joint Profit Maximisation (*M*) versus Collaborative Delegation (*CD*)	Collaborative Delegation (*CD*) versus Independent Profit Maximisation (*N*)	Independent Profit Maximisation (*N*) versus Independent Strategic Delegation (*ID*)	Rank order of outcomes
$x_i^M - x_i^{CD} = \frac{\gamma}{2(\gamma-1)(9\gamma-8)} > 0$	$x_i^{CD} - x_i^N = \frac{3\gamma}{(3\gamma-2)(9\gamma-8)} > 0$	$x_i^N - x_i^{ID} = \frac{3(\gamma-1)}{(3\gamma-2)(9\gamma-7)} > 0$	$x_i^M > x_i^{CD} > x_i^N > x_i^{ID}$
$p_i^M - p_i^{CD} = -\frac{\gamma(3\gamma-2)}{2(\gamma-1)(9\gamma-8)} < 0$	$p_i^{CD} - p_i^N = -\frac{\gamma}{(3\gamma-2)(9\gamma-8)} < 0$	$p_i^N - p_i^{ID} = -\frac{\gamma-1}{(3\gamma-2)(9\gamma-7)} < 0$	$p_i^M < p_i^{CD} < p_i^N < p_i^{ID}$
$Q^M - Q^{CD} = \frac{(1+\gamma)(2+3\gamma)}{2(\gamma-1)(9\gamma-8)} > 0$	$Q^{CD} - Q^N = \frac{2\gamma}{(3\gamma-2)(9\gamma-8)} > 0$	$Q^N - Q^{ID} = \frac{2(\gamma-1)}{(3\gamma-2)(9\gamma-7)} > 0$	$Q^M > Q^{CD} > Q^N > Q^{ID}$
$F_i^M - F_i^{CD} = \frac{\gamma^2(17\gamma-16)}{8(\gamma-1)^2(9\gamma-8)^2} > 0$	$F_i^{CD} - F_i^N = \frac{3\gamma^2(21\gamma-16)}{2(3\gamma-2)^2(9\gamma-8)^2} > 0$	$F_i^N - F_i^{ID} = \frac{3\gamma(\gamma-1)(15\gamma-11)}{2(3\gamma-2)^2(9\gamma-7)^2} > 0$	$F_i^M > F_i^{CD} > F_i^N > F_i^{ID}$
$\pi_i^M - \pi_i^{CD} = \frac{\gamma^2}{8(\gamma-1)(9\gamma-8)} > 0$	$\pi_i^{CD} - \pi_i^N = \frac{\gamma^2}{2(3\gamma-2)(9\gamma-8)} > 0$	$\pi_i^N - \pi_i^{ID} = \frac{(\gamma-1)(27\gamma^2-31\gamma+8)}{2(3\gamma-2)^2(9\gamma-7)^2} > 0$	$\pi_i^M > \pi_i^{CD} > \pi_i^N > \pi_i^{ID}$
$\Pi^M - \Pi^{CD} = \frac{\gamma^2}{4(\gamma-1)(9\gamma-8)} > 0$	$\Pi^{CD} - \Pi^N = \frac{\gamma^2}{(3\gamma-2)(9\gamma-8)} > 0$	$\Pi^N - \Pi^{ID} = \frac{(\gamma-1)(27\gamma^2-31\gamma+8)}{(3\gamma-2)^2(9\gamma-7)^2} > 0$	$\Pi^M > \Pi^{CD} > \Pi^N > \Pi^{ID}$
$CS^M - CS^{CD} = \frac{\gamma^2(3\gamma-2)(15\gamma-14)}{8(\gamma-1)^2(9\gamma-8)^2} > 0$	$CS^{CD} - CS^N = \frac{2\gamma^2(9\gamma-7)}{(3\gamma-2)^2(9\gamma-8)^2} > 0$	$CS^N - CS^{ID} = \frac{2(\gamma-1)(9\gamma^2-8\gamma+1)}{(3\gamma-2)^2(9\gamma-7)^2} > 0$	$CS^M > CS^{CD} > CS^N > CS^{ID}$
$W^M - W^{CD} = \frac{\gamma^2(63\gamma^2-106\gamma+44)}{8(\gamma-1)^2(9\gamma-8)^2} > 0$	$W^{CD} - W^N = \frac{\gamma^2(27\gamma-22)}{(3\gamma-2)^2(9\gamma-8)^2} > 0$	$W^N - W^{ID} = \frac{(\gamma-1)(45\gamma^2-47\gamma+8)}{(3\gamma-2)^2(9\gamma-7)^2} > 0$	$W^M > W^{CD} > W^N > W^{ID}$

Strategic Incentives for Complementary Producers to Innovate for Efficiency and Support Sustainability

Highlights

- Complementary producers face conflicting private and joint incentives to innovate
- Independent decision-making results in complementors underinvesting in innovation
- Industrywide commitments to innovate for cost reduction can counter underinvestment
- Governments can encourage innovation with industrywide waste reduction targets
- Waste reduction commitments support innovation, lean operations and sustainability