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Abstract

Several competition authorities consider the exemption of horizontal agreements among firms from antitrust liability if the agreements sufficiently promote public interest objectives such as sustainable consumption and production. We show that when consumers value sustainable products and firms choose investments in sustainability before choosing output or prices, coordination of output choices or prices boosts investments in sustainability and may even enhance consumer surplus when products are sufficiently close substitutes and the marginal cost of investment in sustainability is relatively low. By contrast, coordination of investments in sustainability leads to lower investments and harms consumers.

JEL-codes: K21, L13, L40, Q01

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1 Introduction

Sustainable consumption and production (SCP), which improves resource efficiency and minimizes pollution and waste, is considered as one solution to environmental challenges such as climate change, pollution, and depletion of resources.[1] Many governments already promote SCP, such as green energy, biological food, and fair trade products, using various policies, including performance standards and mandatory labels, taxes and subsidies, and public campaigns and education (OECD, 2008). Motivated by a concern that competition may encourage firms to offer unsustainable products, it has been recently suggested that exempting horizontal agreements from cartel liability may be another way to promote SCP.

In the U.S., antitrust agencies focus solely on competitive considerations and do not weigh broader public interest considerations like SCP in antitrust proceedings.[2] The European Commission exempted in 1999 a horizontal agreement among manufacturers of washing machines to discontinue energy inefficient models, both on the grounds that the savings of electricity and water directly benefit consumers and that the environmental benefits of the agreement exceed its potential anticompetitive effects.[3] Since then, however, the Commission has been reluctant to weigh general public interest considerations in its cartel decisions. While the Commission clarified that goals pursued by other Treaty provisions, such environmental protection, can be taken into account to the extent that they can be subsumed under

[1] The 1994 Oslo Symposium on Sustainable Consumption defines sustainable consumption as: "The use of services and related products which respond to basic needs and bring a better quality of life while minimizing the use of natural resources and toxic materials as well as emissions of waste and pollutants over the life cycle of the service or product so as not to jeopardize the needs of future generations." See OECD (1999).

[2] Adler (2004) argues that competion among fishermen may lead to fishery depletion, and claims that "conservation cartels," which control catches, may solve the tragedy of the commons in fishing, albeit they also raise prices in the short-run. The U.S. federal courts found several fishermen associations guilty of conspiracy in restraint of trade under the Sherman Act and held that conservation of fisheries does not free the associations from the restrictive provisions of the antitrust act.

[3] European Commission Decision, *Case IV.F.1/36.718. CECED*, 24 January 1999. The exemption was given under Paragraph 3 of Article 81—later replaced by Article 101(3) TFEU. Importantly, the Commission determined that the agreement does not eliminate competition as regards prices, washing performance, or brand image. The exemption was extended in 2001 to agreements to improve the energy efficiency of dishwashers and water heaters. See European Commission (2001a).

the four conditions of Article 101(3), including that they lead to a net benefit for consumers in the same relevant market, no further exemptions on sustainability grounds were given and the Commission's 2011 Guidelines on Horizontal Agreements no longer contains a separate assessment of environmental agreements.[4]

The Dutch Authority for Consumers and Markets (ACM) has grown receptive to claims that horizontal agreements may promote public interest objectives, and pioneered the implementation of cartel exemptions aimed at improving SCP, applying the conditions of Article 101(3) (ACM, 2013a).[5] The public interest defense had been invoked in the Netherlands in 2003 by North Sea shrimp fishermen, who claimed on appeal that horizontal agreement to restrict the amount of harvested shrimp promote sustainable fishing methods that are less damaging to the seabed (NMa, 2003 and Aviat et al., 2011). While the appeal was denied, the NMa (the ACM's predecessor) issued in 2011 a statement in which it welcomed plans to promote sustainable shrimp harvesting methods, but stated that horizontal agreements were not necessary for this purpose (NMa, 2011). Promotion of a sustainability interest as grounds for a cartel exemption was similarly argued in 2008, after the Dutch Royal association 'The Friesian Horses Pedigree' sued several members for exceeding their stallions' breeding quota. The association claimed that the quotas are needed to prevent inbreeding and thereby conserve the Friesian pedigree and for this reason should be exempt from the cartel law. The court agreed, and while the NMa was sympathetic to the claim, it later asked the association to find less restrictive means to control inbreeding (NMa, 2009, p. 45).

The first true test case for the Dutch sustainability defense emerged in the context of the 'Energy Agreement for Sustainable Growth,' which is a nation-wide contract led

[4] The Commission's 2011 Guidelines on Horizontal Agreements mention environmental benefits only briefly in passing, as one example of standards in general, whereas the 2001 Guidelines which they replaced contained a separate chapter on assessing environmental agreements for exemption under 81(3). Several legal scholars, including Monti (2002), Townley (2009) and Kingston (2011), nevertheless argue that the EU Treaties and case-law of the European courts allow, or even demand consideration of wider public interests.

[5] In 2014, the Dutch Ministry of Economic Affairs issued a policy rule that: "In the application of Article 6(3) of the competition law [the Dutch equivalent of 101(3) TFEU] the ACM considers in its assessment of the conditions whether [. . .] in agreements that restrict competition made in order to enhance sustainability, a fair share of the improvements benefits "users" in the long run." Netherlands Minister of Economic Affairs (2014), Article 2.

by the Netherlands government to switch to green energy (see SER, 2013). As part of the agreement, Dutch energy companies agreed to close down five coal power plants which accounted for approximately 10% of the Dutch generating capacity. In an informal decision, the ACM stated that closing down the power plants would raise energy prices and therefore harm consumers, and maintained that the environmental benefits of the agreement were insufficient to offset the harm (see ACM, 2013b, and Kloosterhuis and Mulder, 2015).[6]

The ACM also gave an informal decision in the 'Chicken of Tomorrow' case. The case involved Dutch supermarkets, broiler farmers, and broiler meat processors, who responded to a public outcry against the poor living conditions of chickens in factory farms, by making arrangements to sell chicken meat produced under enhanced animal welfare-friendly conditions. Although the ACM welcomed the initiative, it considered the supermarkets' agreement to remove regular chicken meat from their shelves an unnecessary restraint of competition and concluded that although consumers are prepared to pay more for sustainable chicken meat, on balance they would not benefit from the initiative (ACM, 2015).

A number of other arrangements seek exemption from cartel prohibition on the grounds that they promote SCP. For instance, the Fair Wear Foundation (FWF), an independent non-profit organization that works with companies and factories to improve labour conditions for garment workers in developing countries, has recently obtained a legal opinion which states that its actions do not violate European competition law (See Arnold & Porter (UK) LLP, 2015). Another case in point may be the coordinated decisions of tour operators to stop offering elephant back rides, which are deemed cruel to elephants, in holiday travel itineraries.[7]

[6] In essence, the ACM found that the plants' closure would improve air quality in the Netherlands by reducing emission of carbon dioxide (CO2), sulfur dioxide (SO2), nitrogen oxide (NOx) and fine particles, and argued that "in principle, this can be taken into consideration when assessing the question of whether Section 6 (3) and Article 101 (3) TFEU respectively apply." Yet, the ACM concluded that the lower CO2 emissions would be offset by higher emissions by other parties that would acquire the plants' emission allowances through the EU system of emissions trading (ETS) to such an extent that the environmental benefits for Dutch consumers would be too limited to offset their harm due to higher prices—even if the world population as a whole would benefit.

[7] See e.g., http://www.nltimes.nl/2013/08/17/step-away-from-elephants/.

The public interest in general, and SCP in particular, are elusive concepts, and it is not obvious how to weigh them against the potential anticompetitive effects of various restraints of trade. Moreover it is not even obvious that horizontal agreements necessarily boost the incentives of firms to invest in SCP. Hence, it is unclear whether competition policy is the right mechanism to promote SCP, even if the competition authority has the expertise to determine the right level of SCP and how much society is willing to sacrifice in order to achieve it.[8] In this paper, we take a first step towards addressing these questions by asking the following simple question: assuming that consumers are willing to pay extra for sustainable products like cleaner energy, sustainable meat and travel, or fair trade clothing, can horizontal agreements among competing firms promote SCP?

To address this question, we consider a two-stage duopoly model in which firms first choose how much to invest in the sustainability of their respective products, and then compete in the product market (in most of the paper firms compete by choosing quantities, but the results generalize to price competition). A key assumption in our model is that the products of the two firms are differentiated, and the willingness of consumers to pay increases with the product's sustainability level.[9] The two firms internalize sustainability considerations only insofar as they increase the willingness of consumers to pay. We compare four scenarios: competition in both stages; coordination in the choice of sustainability, followed by competition in output levels (sustainability coordination); noncooperative choices of sustainability, followed by collusion on output levels (production cartel); and collusion in both stages.

Our main finding is that production cartels promote sustainability and may even

[8] Some competition authorities do take into account noncompetition-related goals, especially in merger control cases. While this is true in many developing countries, it is also true in some OECD countries. See Shyam-Khemani (2002) and Capobianco and Nagy (2015).

[9] The latter assumption is consistent with the ACM's approach as described in the ACM's vision document on competition and sustainability: "...it is essential to note that consumers may also find product characteristics related to sustainability important, and may therefore value the fact that products are produced in an environmentally friendly or animal-friendly manner" (ACM, 2014, p. 7). Moreover, a study by Nielsen reveals that 55% of global online consumers across 60 countries say they are willing to pay more for "products and services provided by companies that are committed to positive social and environmental impact" (Nielsen, 2014).

enhance consumer surplus, while sustainability coordination induces the lowest levels of investment in sustainability and make consumers worse off than they are absent collusion. Although production cartels may enhance consumer surplus, under a broad range of parameters, they actually harm consumers. The requirement for granting an exemption from cartel prohibition that consumers are compensated may remedy this problem. Our analysis shows however that although this provision ensures that consumers are not harmed, firms end up investing in sustainability less than they do absent a cartel, which implies in turn that collusion offers no benefits.

The economic literature on the interaction between competition and public interest consideration is still in its infancy. Hashimzade and Myles (2014) study a model in which firms simultaneously choose prices and investments in environmental improvements. The latter may lower production costs and may also boost the firms' brand image and hence the demand they face. They show that when firms form a cartel, they raise prices and invest less because the strategic motivation to invest is weakened. Hashimzade and Myles interpret this result as suggesting that the public interest defence cannot be sustained since cartel activity leads to lower environmental contributions. Our analysis, which considers sequential choice of investment and product market competition, shows by contrast that under a production cartel, firms have a stronger incentive to invest. Schinkel and Toth (2016) study the extent to which it is possible to compensate consumers for price increases of a private good with a sufficiently high level of public goods provision. They find that such compensation is impossible if consumers are sufficiently heterogenous, as those who consume most of the cartelized private good value the public good least. In addition, collusive provision of the public good crowds out private contributions.

The remainder of this paper is organized as follows. In Section 2, we present our two-stage model and in Section 3 we characterize the equilibrium of the model under the four scenarios mentioned above. In Section 4 we compare the equilibrium across the four scenarios and present our main results. In Section 5, we examine the welfare implication of a policy rule which exempts firms from cartel prohibition provided that consumer surplus under collusion is at least as high as it is without collusion. Concluding remarks are in Section 6.

2 A model of sustainable product choice

Two firms produce differentiated goods at constant marginal cost k. The demand functions for the two goods are derived from the preferences of a representative consumer, whose utility function is quadratic, and given by:

$$u(q_1, q_2, v_1, v_2) = (a + v_1)\,q_1 + (a + v_2)\,q_2 - \frac{q_1^2 + q_2^2 + 2\gamma q_1 q_2}{2} + m, \qquad (1)$$

where q_1 and q_2 are the quantities of the two goods, v_1 and v_2 are measures of the "sustainability" level of the two goods, m is income spent on all other goods, $a > 0$ is a utility parameter, and $\gamma \in (0, 1)$ is a measure of the degree of product differentiation, with lower value of γ representing a larger degree of differentiation.

A higher degree of sustainability, i.e., higher values of v_1 and v_2, may represent lower levels of CO2 emissions, more use of renewable energy, better living conditions of animals in factory farms, or improved working conditions of production workers. The utility function (1) captures the idea that consumers care about sustainable consumption and have a higher willingness to pay when products are more sustainable ($\frac{\partial^2 u(q_1,q_2,v_1,v_2)}{\partial q_1 \partial v_1} > 0$).[10] For example, consumers of chicken meat may agree to pay a premium for meat if they know that chickens are raised in welfare-friendly conditions. Conversely, consumption may drop following stories about the poor living conditions of chickens in factory farms. Likewise, consumers may wish to pay a premium for energy efficient washing machines and dish washers, and may feel better buying clothes that were produced in factories that pay their workers fair wages, or use energy when it is produced with "green" technologies. It should be noted that our model does not reflect wider public interests or the concerns of non consumers, like the concerns of vegetarians about the wellbeing of animals. Firms care in our model about sustainability only insofar as it raises the willingness of consumers to pay.[11] This setup is consistent with the policy requirement that actual consumers in the relevant market should be compensated by the SCP benefits.

[10] Bagnoli and Watts (2003) also study a model in which firms can attract socially minded consumers by investing in environmentally friendly or socially responsible activities.

[11] As mentioned in the Introduction, Schinkel and Toth (2016) study the tradeoff between cartel price overcharges and the benefits to consumers from improvements in the environment and in public health.

Maximizing the representative consumer's utility function subject to a budget constraint, $p_1 q_1 + p_2 q_2 + m = I$, where p_1 and p_2 are the prices of the two goods and I is income, yields the following inverse demand functions:

$$p_1 = a + v_1 - q_1 - \gamma q_2, \qquad p_2 = a + v_2 - q_2 - \gamma q_1. \tag{2}$$

The strategic interaction between the two firms evolves in two stages: in Stage 1, the two firms choose the sustainability level of their goods, v_1 and v_2; the associated costs of investment in sustainability are $\frac{rv_1^2}{2}$ and $\frac{rv_2^2}{2}$, where $r \geq 1$. In Stage 2, the two firms observe v_1 and v_2 and simultaneously choose their output levels, q_1 and q_2. The profit functions of the two firms are given by

$$\pi_1 (q_1, q_2, v_1, v_2) = (a + v_1 - q_1 - \gamma q_2) q_1 - k q_1 - \frac{rv_1^2}{2}, \tag{3}$$

and

$$\pi_2 (q_1, q_2, v_1, v_2) = (a + v_2 - q_2 - \gamma q_1) q_2 - k q_2 - \frac{rv_2^2}{2}. \tag{4}$$

Three remarks about our setup are now in order. First, our setting fits the motivating examples mentioned in the Introduction quite well. Indeed, in all examples, investment in SCP may well boost the willingness of consumers to pay, and quantity competition is a reasonable approximation for the strategic interaction among firms, especially in the North Sea shrimp case, the Friesian Horses case, the agreement to close coal power plants, and the Chicken of Tomorrow initiative. However, below we show that our qualitative results generalize to the case of price competition, which may fit better the washing machines case, the garments industry, and the elephant back rides tours. The only caveat is that under price competition, the parameter r has to be sufficiently large to ensure that the profit function of each firm is a concave function of the firm's sustainability level.[12]

Second, in addition to raising the willingness of consumers to pay at a fixed cost that is independent of production volume, investment in sustainability could just as well affect the marginal cost of production, k. It is straightforward to extend our model to the case where the marginal cost of firm i is given by $k + \beta v_i$, where $\beta > 0$ if sustainability raises

[12] Under price competition, the demand functions are obtained by solving the demand system (2) for q_1 and q_2, given p_1 and p_2. That is, $q_1 = \frac{a+v_1-p_1-\gamma(a+v_2-p_2)}{1-\gamma^2}$ and $q_2 = \frac{a+v_2-p_2-\gamma(a+v_1-p_1)}{1-\gamma^2}$.

the marginal cost of production (which is plausible in the North Sea shrimps case or the Chicken of Tomorrow initiative), or $\beta < 0$ if sustainability is associated with lower marginal cost of production (which would be the case if, say, coal plants are replaced by renewable energy like wind, solar, or hydroelectric power). So long as $\beta < 1$, our qualitative results do not change. This is because v_i enters the profit function of firm i as $v_i q_i - \frac{r v_i^2}{2}$, whereas when the marginal cost of production is $k + \beta v_i$, it enters it as $(1-\beta) v_i q_i - \frac{r v_i^2}{2}$. However, when $\beta > 1$, the extra cost of SCP exceed the extra benefit, so firms would have no reason to invest in SCP in our model.[13]

Third, it might be that investment in SCP by one firm benefits other firms, say by improving the industry's reputation as a whole (e.g., consumers hear that firms invested in SCP, but are not entirely sure which firms invested), or by reducing the incentive of public pressure groups to mount negative campaigns against firms. Either way, the demand that non investing firms face may be higher than it would otherwise be. This effect can be captured in our model by assuming that the utility function of the representative consumer includes the term $s(v_2 q_1 + v_1 q_2)$, where $s \in (0,1)$ is a measure of the degree of investment spillovers. The resulting inverse demand functions are then

$$p_1 = a + v_1 + s v_2 - q_1 - \gamma q_2, \qquad p_2 = a + v_2 + s v_1 - q_2 - \gamma q_1. \tag{5}$$

Below we will examine briefly how such investment spillovers affect the willingness of firms to invest in SCP.

3 The equilibrium

In this section, we characterize the subgame perfect equilibrium in our two-stage model under four alternative market structures: (i) the two firms compete in both stages; (ii) the two firms coordinate their choices of sustainability levels in Stage 1, but then compete in Stage 2 when they choose their output levels (sustainability coordination); (iii) the two firms choose their levels of sustainability in Stage 1 noncooperatively, but then collude in Stage 2 when

[13] In a different model though, in which horizontal agreements may be deemed illegal, firms may wish to invest in SCP even when $\beta > 1$, if the investments allow them to use the public interest defense in antitrust proceedings.

they choose their output levels (production cartel); and (iv) the two firms collude in both stages of the game (full collusion). Our goal is to study how the different types of collusion compare in affecting the choice of sustainability and ultimately consumers' welfare.

It should be noted that the horizontal agreements that we study are not illicit cartels: rather the agreements are exempt from antitrust liability either ex ante after advance notification, or ex post, when firms invoke the public interest defense in antitrust proceedings. Hence we will assume that the agreements can be contractible and that firms choose them to maximize their joint profit and can use side payments to divide the joint profit between them (though since the equilibrium in our model is symmetric, no side payments are actually needed). In any event, in the Appendix, we consider an infinitely repeated version of our model and use it to study the conditions that ensure that horizontal agreements are self enforcing.

3.1 Competition in both stages

In Stage 2, given v_1 and v_2, the two firms choose their output levels, q_1 and q_2, to maximize their respective profits, given by (3) and (4). The resulting Nash equilibrium output levels are:

$$q_1^*(v_1, v_2) = \frac{2(A + v_1) - \gamma(A + v_2)}{4 - \gamma^2}, \qquad q_2^*(v_1, v_2) = \frac{2(A + v_2) - \gamma(A + v_1)}{4 - \gamma^2}, \tag{6}$$

where $A \equiv a - k$. Substituting from (6) into (3) and (4), the reduced form profit functions, given v_1 and v_2, are

$$\pi_1(v_1, v_2) = (q_1^*(v_1, v_2))^2 - \frac{rv_1^2}{2}, \qquad \pi_2(v_1, v_2) = (q_2^*(v_1, v_2))^2 - \frac{rv_2^2}{2}. \tag{7}$$

Note that $\pi_1(v_1, v_2)$ is concave in v_1 and $\pi_2(v_1, v_2)$ is concave in v_2. In Stage 1, the two firms simultaneously choose their sustainability levels, v_1 and v_2, to maximize $\pi_1(v_1, v_2)$ and $\pi_2(v_1, v_2)$. The resulting Nash equilibrium is defined by the following first-order conditions:

$$\frac{\partial \pi_1(v_1, v_2)}{\partial v_1} = 2q_1^*(v_1, v_2)\frac{\partial q_1^*(v_1, v_2)}{\partial v_1} - rv_1 = 0,$$

and

$$\frac{\partial \pi_2(v_1, v_2)}{\partial v_2} = 2q_2^*(v_1, v_2)\frac{\partial q_2^*(v_1, v_2)}{\partial v_2} - rv_2 = 0.$$

Solving the two conditions, the sustainability levels under competition in both stages are given by

$$v_1^* = v_2^* = v^* = \frac{4A}{r\left(2-\gamma\right)\left(2+\gamma\right)^2 - 4}. \tag{8}$$

3.2 Sustainability coordination

Now suppose that the two firms choose their sustainability levels v_1 and v_2 jointly in Stage 1, but then they go on to compete in Stage 2 when they choose their production levels. This situation resembles a research joint venture.[14]

In our model, when firms coordinate their investments in sustainability in Stage 1, they anticipate that the equilibrium output levels in Stage 2 will be given by (6). Hence, the two firms choose v_1 and v_2 in Stage 1 to maximize the sum of their reduced form profit functions $\pi_1\left(v_1, v_2\right) + \pi_2\left(v_1, v_2\right)$. The resulting choices in Stage 1 are then given by the following first-order conditions:

$$\frac{\partial\left(\pi_1\left(v_1, v_2\right) + \pi_2\left(v_1, v_2\right)\right)}{\partial v_1} = 2q_1^*\left(v_1, v_2\right)\frac{\partial q_1^*\left(v_1, v_2\right)}{\partial v_1} + 2q_2^*\left(v_1, v_2\right)\frac{\partial q_2^*\left(v_1, v_2\right)}{\partial v_1} - rv_1 = 0,$$

and

$$\frac{\partial\left(\pi_1\left(v_1, v_2\right) + \pi_2\left(v_1, v_2\right)\right)}{\partial v_2} = 2q_2^*\left(v_1, v_2\right)\frac{\partial q_2^*\left(v_1, v_2\right)}{\partial v_2} + 2q_1^*\left(v_1, v_2\right)\frac{\partial q_1^*\left(v_1, v_2\right)}{\partial v_2} - rv_2 = 0.$$

Solving the two conditions yields the equilibrium choices of sustainability levels

$$v_1^{sc} = v_2^{sc} = v^{sc} = \frac{2A}{r\left(2+\gamma\right)^2 - 2}, \tag{9}$$

where the superscript sc stands for "sustainability coordination."

3.3 Production cartel

Alternatively, suppose that the two firms choose their investments in sustainability v_1 and v_2 in Stage 1 noncooperatively, but then collude in Stage 2 when they choose their output

[14] For instance, Choi (1993) considers a two-stage model in which, after forming an research joint venture, firms perfectly coordinate their R&D investments, but then choose their strategies in Stage 2 (prices in Choi's model) independently.

levels, q_1 and q_2. This situation, where firms coordinate their strategies in Stage 2, but compete in Stage 1, is often referred to in the literature as semicollusion.[15]

Starting with Stage 2, the output levels q_1 and q_2 are chosen to maximize the sum of profits given by (3) and (4).[16] The resulting output levels are

$$q_1^{pc}(v_1, v_2) = \frac{A + v_1 - \gamma(A + v_2)}{2(1-\gamma^2)}, \qquad q_2^{pc}(v_1, v_2) = \frac{A + v_2 - \gamma(A + v_1)}{2(1-\gamma^2)}, \tag{10}$$

where the superscript pc stands for "production cartel." Substituting $q_1^{pc}(v_1, v_2)$ and $q_2^{pc}(v_1, v_2)$ into (3) and (4) yields the reduced form profits of the two firms, as functions of v_1 and v_2:

$$\pi_1^{pc}(v_1, v_2) = q_1^{pc}(v_1, v_2)\frac{A + v_2}{2} - \frac{rv_1^2}{2}, \qquad \pi_2^{pc}(v_1, v_2) = q_2^{pc}(v_1, v_2)\frac{A + v_1}{2} - \frac{rv_2^2}{2}.$$

These profit functions differ from (7) in that here the output levels are chosen in Stage 2 jointly, while in (7) they are chosen in Stage 2 noncooperatively. Notice that given $q_1^{pc}(v_1, v_2)$ and $q_2^{pc}(v_1, v_2)$, the markup of good 1 is $\frac{A+v_2}{2}$ and the markup of good 2 is $\frac{A+v_1}{2}$. That is, the markup of each firm is independent of its own investment in sustainability and only depends on the rival's investment. The revenue of each firm then depends on its investment in sustainability only through the firm's output, but not through the price at which the firm sells its good. The profit of each firm is a concave function of the firm's sustainability level unless γ is too close to 1 (as r increases, the profit functions are concave in the sustainability levels for a larger set of values of γ).

In Stage 1, the two firms simultaneously choose v_1 and v_2 to maximize their respective profits. The resulting Nash equilibrium is defined by the following first-order conditions:

$$\frac{\partial \pi_1^{pc}(v_1, v_2)}{\partial v_1} = \frac{\partial q_1^{pc}(v_1, v_2)}{\partial v_1}\frac{A + v_2}{2} - rv_1 = 0,$$

[15] See e.g., Fershtman and Gandal (1994) and Brod and Shivakumar (1999). Matsui (1989) also studies a model of semicollusion, although he does not use this terminology.

[16] When $v_1 \neq v_2$, the profit functions of the two firms are asymmetric and hence, absent side payments, the two firms may not wish to maximize their joint profits. A possible alternative is to use the Nash bargaining solution to determine the collusive agreement, see e.g., Harrington (1989 and Harrington (1991), in which firms produce homogenous products and consumers buy from the firms that charge the lowest price in the market. Unfortunately, in our model with differentiated goods this approach makes the analysis intractable. Allowing side payments, we can restrict the analysis to joint profit maximization.

and

$$\frac{\partial \pi_2^{pc}(v_1, v_2)}{\partial v_2} = \frac{\partial q_2^{pc}(v_1, v_2)}{\partial v_2} \frac{A + v_1}{2} - r v_2 = 0.$$

Solving the two conditions, the Nash equilibrium levels of sustainability under a production cartel are given by

$$v_1^{pc} = v_2^{pc} = v^{pc} = \frac{A(2-\gamma)}{4r(1-\gamma^2) - (2-\gamma)}. \tag{11}$$

3.4 Full collusion

Finally, suppose that the two firms collude in both stages. Under full collusion, the outputs in Stage 2 are given by (10). However, unlike the case of production cartel, where v_1 and v_2 are chosen noncooperatively, here v_1 and v_2 are chosen to maximize the sum of the reduced form profits $\pi_1^{pc}(v_1, v_2) + \pi_2^{pc}(v_1, v_2)$. The resulting sustainability levels are given by the following pair of first order conditions:

$$\frac{\partial \pi_1^{pc}(v_1, v_2) + \pi_2^{pc}(v_1, v_2)}{\partial v_1} = \frac{\partial q_1^{pc}(v_1, v_2)}{\partial v_1} \frac{A + v_2}{2} + \frac{\partial q_2^{pc}(v_1, v_2)}{\partial v_1} \frac{A + v_1}{2} + \frac{q_2^{pc}(v_1, v_2)}{2} - r v_1 = 0$$

and

$$\frac{\partial \left(\pi_1^{pc}(v_1, v_2) + \pi_2^{pc}(v_1, v_2)\right)}{\partial v_2} = \frac{\partial q_2^{pc}(v_1, v_2)}{\partial v_2} \frac{A + v_1}{2} + \frac{\partial q_1^{pc}(v_1, v_2)}{\partial v_2} \frac{A + v_2}{2} + \frac{q_1^{pc}(v_1, v_2)}{2} - r v_2 = 0.$$

Solving the two conditions yields:

$$v_1^{fc} = v_2^{fc} = v^{fc} = \frac{A}{2r(1+\gamma) - 1}, \tag{12}$$

where the superscript fc stands for "full collusion."

3.5 Comparing sustainability levels

Having solved for the equilibrium levels of sustainability under the four scenarios, we now compare them and report the following result.

Proposition 1: $v^{pc} > v^{*} > v^{fc} > v^{sc}$: *among the four regimes, sustainability is highest under a production cartel, followed by competition in both stages, followed by full collusion. Sustainability is lowest when firms coordinate their sustainability choices in Stage* 1*, but then compete in Stage* 2*.*

Proof: To derive the result, note first that

$$v^{pc} - v^{*} = \frac{A\gamma^{2}\left(8+\gamma^{2}\right)r}{\left(4r\left(1-\gamma^{2}\right)-\left(2-\gamma\right)\right)\left(r\left(2-\gamma\right)\left(2+\gamma\right)^{2}-4\right)} > 0.$$

Second note that

$$v^{*} - v^{fc} = \frac{A\gamma\left(4+2\gamma+\gamma^{2}\right)r}{\left(r\left(2-\gamma\right)\left(2+\gamma\right)^{2}-4\right)\left(2r\left(1+\gamma\right)-1\right)} > 0.$$

Finally note that

$$v^{fc} - v^{sc} = \frac{A\gamma^{2}r}{\left(2r\left(1+\gamma\right)-1\right)\left(r\left(2+\gamma\right)^{2}-2\right)} > 0.$$

■

Proposition 1 suggests that allowing firms to coordinate their investments in sustainability hinders investments in SCP, while allowing a production cartel promote such investments. The latter result is consistent with Fershtman and Gandal (1994) and Brod and Shivakumar (1999); both papers show that under semicollusion (firms first choose investments noncooperatively but then collude in the product market), firms invest more than they do in the absence of any form of collusion.[17]

This result stands in stark contrast to the emerging policy, at least in the Netherlands, where competition authorities are willing to allow firms to coordinate their choices of sustainability, but do not allow them to coordinate their output or prices.[18] Indeed, all the cases mentioned in the Introduction involved sustainability initiatives directly and ruled

[17] Matsui (1989) shows that if cartel members are allowed to produce more when they invest more before the cartel is formed (in his model, investment lowers the total cost and marginal cost of production), then firms will indeed invest more than they would absent collusion (by investing, each firm tries to increase its share in the collusive profits).

[18] The ACM, for instance, maintains that "Arrangements relating to the selling price generally fall under the cartel prohibition." (ACM, 2014, p. 8).

out hard core collusion, which in our model corresponds to sustainability cooperation. For example, the North Sea shrimp fishermen were explicitly prohibited from restricting output, but were allowed to coordinate sustainability efforts. Likewise, the ACM did not approve the agreement to remove regular chicken meat from supermarket shelves, although in general it welcomed the Chicken of Tomorrow initiative to improve the living conditions of broilers. Similarly, it did not approve the joint agreement to close coal power plants, although it did not object the wider talks about moving to more sustainable energy production. Proposition 1 suggests that the policy of allowing sustainability coordination but not production cartels may be misguided.

Proposition 1 is quite general and holds even if we change the functional forms that we assume here and even if firms compete in prices rather than quantities. To see this and also clarify the intuition behind Proposition 1, let us generalize the choice of sustainability across all four scenarios. To this end, note that given v_1 and v_2, the reduced form profits in Stage 1 can be written as follows:

$$\pi_1\left(q_1\left(v_1,v_2\right),q_2\left(v_1,v_2\right),v_1,v_2\right),\qquad \pi_2\left(q_1\left(v_1,v_2\right),q_2\left(v_1,v_2\right),v_1,v_2\right).$$

where $q_1\left(v_1,v_2\right)=q_1^*\left(v_1,v_2\right)$ and $q_2\left(v_1,v_2\right)=q_2^*\left(v_1,v_2\right)$ when output levels are chosen noncooperatively in Stage 2 and $q_1\left(v_1,v_2\right)=q_1^{pc}\left(v_1,v_2\right)$ and $q_2\left(v_1,v_2\right)=q_2^{pc}\left(v_1,v_2\right)$ when output levels are chosen cooperatively in Stage 2. Note further that in each of the four scenarios, v_1 is chosen to maximize

$$\pi_1\left(q_1\left(v_1,v_2\right),q_2\left(v_1,v_2\right),v_1,v_2\right)+\phi\pi_2\left(q_1\left(v_1,v_2\right),q_2\left(v_1,v_2\right),v_1,v_2\right),$$

where $\phi=1$ if v_1 and v_2 are chosen cooperatively in Stage 1 (under sustainability coordination and full collusion) and $\phi=0$ if v_1 and v_2 are chosen noncooperatively in Stage 1 (under competition in both stages and production cartel). Hence, the first-order condition for v_1 in all four scenarios can be written as follows:

$$\begin{aligned}&\frac{\partial\pi_1}{\partial q_1}\frac{\partial q_1\left(v_1,v_2\right)}{\partial v_1}+\frac{\partial\pi_1}{\partial q_2}\frac{\partial q_2\left(v_1,v_2\right)}{\partial v_1}+\frac{\partial\pi_1}{\partial v_1}\\&+\phi\left[\frac{\partial\pi_2}{\partial q_1}\frac{\partial q_1\left(v_1,v_2\right)}{\partial v_1}+\frac{\partial\pi_2}{\partial q_2}\frac{\partial q_2\left(v_1,v_2\right)}{\partial v_1}+\frac{\partial\pi_2}{\partial v_1}\right]=0.\end{aligned}\tag{13}$$

The first order condition for v_2 is analogous.

When output levels are chosen noncooperatively in Stage 2 (under competition in both stages and under sustainability coordination), $q_1(v_1, v_2) = q_1^*(v_1, v_2)$, $q_2(v_1, v_2) = q_2^*(v_1, v_2)$, and $\frac{\partial \pi_1}{\partial q_1} = \frac{\partial \pi_2}{\partial q_2} = 0$. Since $\phi = 0$ under competition in both stages and $\phi = 1$ under sustainability coordination, the first-order condition under competition in both stages is given by

$$\underbrace{\frac{\partial \pi_1}{\partial q_2}\frac{\partial q_2^*(v_1, v_2)}{\partial v_1} + \frac{\partial \pi_1}{\partial v_1}}_{G^*} = 0, \tag{14}$$

and under sustainability coordination it is given by

$$\underbrace{\frac{\partial \pi_1}{\partial q_2}\frac{\partial q_2^*(v_1, v_2)}{\partial v_1} + \frac{\partial \pi_1}{\partial v_1}}_{G^*} + \frac{\partial \pi_2}{\partial q_1}\frac{\partial q_1^*(v_1, v_2)}{\partial v_1} + \frac{\partial \pi_2}{\partial v_1} = 0. \tag{15}$$

When output levels are chosen cooperatively in Stage 2 (under production cartel and under full cartel), $q_1(v_1, v_2) = q_1^{pc}(v_1, v_2)$, $q_2(v_1, v_2) = q_2^{pc}(v_1, v_2)$. Recalling that under a production cartel, $\phi = 0$, the first-order condition becomes

$$\frac{\partial \pi_1}{\partial q_1}\frac{\partial q_1^{pc}(v_1, v_2)}{\partial v_1} + \underbrace{\frac{\partial \pi_1}{\partial q_2}\frac{\partial q_2^{pc}(v_1, v_2)}{\partial v_1} + \frac{\partial \pi_1}{\partial v_1}}_{G^{pc}} = 0. \tag{16}$$

Under a full cartel, $\phi = 1$. Noting in addition that since output levels are chosen cooperatively, $\frac{\partial \pi_1}{\partial q_1} + \frac{\partial \pi_2}{\partial q_1} = \frac{\partial \pi_1}{\partial q_2} + \frac{\partial \pi_2}{\partial q_2} = 0$, the first-order condition reduces to

$$\underbrace{\frac{\partial \pi_1}{\partial v_1}}_{G^* - \frac{\partial \pi_1}{\partial q_2}\frac{\partial q_2^*(v_1, v_2)}{\partial v_1}} + \frac{\partial \pi_2}{\partial v_1} = 0. \tag{17}$$

Using (14), (15), (16), and (17), it is easy to compare the investments in sustainability across the four scenarios. To this end, note first that when output levels are chosen jointly, $\frac{\partial \pi_1}{\partial q_1} + \frac{\partial \pi_2}{\partial q_1} = 0$; since $\frac{\partial \pi_2}{\partial q_1} < 0$, it follows that $\frac{\partial \pi_1}{\partial q_1} > 0$. Since in addition $\frac{\partial q_1^{pc}(v_1, v_2)}{\partial v_1} > 0$ (firm 1 produces more when its sustainability level, and hence the demand it is facing, are higher), the first term in (16) is positive. Moreover, suppose that $\left|\frac{\partial q_2^{pc}(v_1, v_2)}{\partial v_1}\right| > \left|\frac{\partial q_2^*(v_1, v_2)}{\partial v_1}\right|$, i.e., firm 1's sustainability has a stronger effect on firm 2's output when the output levels are chosen cooperatively than when they are chosen independently. It is easy to see from (6) and (10) that this assumption holds in our model. Then, $G^{pc} > G^*$, so the left-hand side of (16) exceeds the left-hand side of (14). This implies in turn that $v_1^{pc} > v_1^*$: firms invest more in sustainability under a production cartel than under competition.

Intuitively, under a production cartel, firm 1 takes into account the positive effect of v_1 on its own output. Under competition in both stages, this effect vanishes, since firm 1's output adjusts to maximize firm 1's profit. This adjustment, which competes away the benefits from investing in SCP, is incomplete under a production cartel since firm 1's output is constrained due to its negative effect on firm 2's profit. A larger investment in sustainability relaxes this constraint and hence provides firm 1 with an extra incentive to invest. Put differently, under a production cartel firms cannot freely choose their production levels, so they compete more intensely in the first stage in which they select their sustainability levels.

Next, note that the square bracketed term in (15) is negative since $\frac{\partial \pi_2}{\partial q_1} < 0$ and $\frac{\partial \pi_2}{\partial v_1} < 0$ (firm 1's output and sustainability levels impose a negative externality on firm 2) and since $\frac{\partial q_1^{sc}(v_1,v_2)}{\partial v_1} > 0$ (firm 1 faces a higher demand when its sustainability is higher). Hence, $v_1^* > v_1^{sc}$: v_1 is higher when the negative externality that firm 1 imposes on firm 2 is ignored under competition in both stages than when the negative externality is internalized under sustainability coordination.

Similarly, note that since $\frac{\partial \pi_1}{\partial q_2} < 0$, $\frac{\partial q_2^{pc}(v_1,v_2)}{\partial v_1} < 0$, $\frac{\partial \pi_2}{\partial v_1} < 0$ (each firm imposes a negative externality on its rival), the left-hand side of (17) is lower than the left-hand side of (14), so $v_1^* > v_1^{fc}$: v_1 is higher under competition in both stages than under collusion in both stages. Once again this is due to the fact that under collusion firm 1 internalizes the negative externality that it imposes on firm 2 and hence it invests less than under competition when it ignores the negative externality on firm 2.

Finally, note that the left-hand side of (15) can be written as $G^* + \frac{\partial \pi_2}{\partial v_1} + \frac{\partial \pi_2}{\partial q_1}\frac{\partial q_1^*(v_1,v_2)}{\partial v_1}$, while the left-hand side of (17) can be written as $G^* + \frac{\partial \pi_2}{\partial v_1} - \frac{\partial \pi_1}{\partial q_2}\frac{\partial q_2^*(v_1,v_2)}{\partial v_1}$. Under symmetry, $\frac{\partial \pi_2}{\partial q_1} = \frac{\partial \pi_1}{\partial q_2}$. Hence, so long as $\frac{\partial q_1^*(v_1,v_2)}{\partial v_1} > \left|\frac{\partial q_2^*(v_1,v_2)}{\partial v_1}\right|$, i.e., v_1 has a larger effect on the sales of firm 1 than on the sales of firm 2, the left-hand side of (17) exceeds the left-hand side of (15) and hence, $v_1^{fc} > v_1^{sc}$. The intuition here is that under both sustainability coordination and full cartel, firm 1 internalizes the negative externality that its sustainability imposes on firm 2. The difference is that under sustainability coordination, the choice of v_1 takes into account the effect of v_1 on firm 1's output which lowers firm 2's profit. Under full cartel, there is no need to take this effect into account since outputs are chosen cooperatively in stage 2. However, the choice of v_1 now takes into account the effect of v_1 on the output of firm 2. Hence if v_1 affects firm 1's output more than it affects firm 2's output, the choice of v_1 will be higher under full collusion than under sustainability coordination.

The above discussion shows that, whenever the two firms impose negative externalities on each other (the output and sustainability of one firm lower the profit and output level of the rival), and firm 1's sustainability has a stronger effect on firm 2's output when the output levels are chosen cooperatively, then $v^{pc} > v^* > \max\left\{v^{fc}, v^{sc}\right\}$, as Proposition 1 shows. In order to show in addition that $v^{fc} > v^{sc}$, we also need to assume that v_1 has a larger effect on firm 1's output than on firm 2's output.

Notice that none of the arguments so far depends on whether the best-response functions in the second stage slope up or slope down. Hence, Proposition 1 does not depend on our assumption that firms choose quantities in the second stage of the game: our results generalize to the case where firms set prices in the second stage of the game, although r has to be sufficiently large in that case to ensure that the profit function of each firm is a concave function of its sustainability level.

We conclude this section by considering the possibility of SCP investment spillovers. To this end, we recompute the equilibrium under the four scenarios using the demand system (5). The results now also depend on the parameter s, which measures the degree of investment spillovers (the analysis so far is a special case where $s = 0$). The analysis reveals that it is still true that $v^{pc} > v^*$ and $v^{fc} > v^{sc}$, as stated in Proposition 1. However, unlike in Proposition 1, now $v^{pc} > v^* > v^{sc}$ only when $s < \frac{\gamma}{2}$, i.e., when investment spillovers are small relative to γ. When $\frac{\gamma}{2} < s < s_1 \equiv \frac{\gamma\left(4+6\gamma-\gamma^2\right)}{8+4\gamma(1-\gamma)+\gamma^3}$, we get $v^{pc} > v^{sc} > v^*$, and when $s > s_1$, we get $v^{sc} > v^{pc}$, where s_1 increase from 0 when $\gamma = 0$ to 1 when $\gamma = 1$. That is, when SCP investment spillovers are large relative to γ, sustainability coordination may lead to more investment in SCP than competition in both stages and even a production cartel, contrary to what Proposition 1 shows.

4 Welfare analysis

So far we have shown that allowing firms to collude in the product market may boost investments in sustainability. The question then is what is the overall effect on welfare once output levels and resulting prices are taken into account. To address this question, note that substituting from (2) into (1), consumer surplus is given by

$$CS(q_1, q_2) = \frac{q_1^2 + q_2^2 + 2\gamma q_1 q_2}{2}. \tag{18}$$

As equation (18) shows, sustainability affects consumers only through the equilibrium levels of production, but not directly. The reason for this is that while consumers are better off when sustainability increases, prices also adjust to reflect the higher willingness of consumers to pay. As can be seen from equation (2), prices increase with sustainability on a one-to-one basis, and since utility is quasi-linear, it also decreases with prices on a one-to-one basis, so the two effects just cancel each other out. This of course does not mean that sustainability does not affect consumers: it does, but the effect works through the consumption levels of the two goods. Specifically, sustainability affects the demands for the two products, which in turn affects the equilibrium prices chosen by the two firms, and this determines the quantities that consumers buy, and hence their consumer surplus.

Using (18) we now establish under what conditions a production cartel will in fact raise total welfare.

Proposition 2: *The ranking of consumer surplus is as follows:*

(i) $CS^* > CS^{sc} > SC^{pc} > CS^{fc}$ *if* $r > \frac{4-\gamma}{2(2-\gamma-\gamma^2)}$,

(ii) $CS^* > CS^{pc} > SC^{sc} > CS^{fc}$ *if* $\frac{4-2\gamma+\gamma^2}{2(1-\gamma)(4-\gamma^2)} < r < \frac{4-\gamma}{2(2-\gamma-\gamma^2)}$, *and*

(iii) $CS^{pc} > CS^* > CS^{sc} > CS^{fc}$ *if* $r < \frac{4-2\gamma+\gamma^2}{2(1-\gamma)(4-\gamma^2)}$.

Since $\frac{4-2\gamma+\gamma^2}{2(1-\gamma)(4-\gamma^2)} < 1$ *when* $\gamma < 0.5567$ *and since by construction* $r \geq 1$, *case (iii) can arise only when* $\gamma > 0.5567$.

Proof: First note that in the symmetric solutions where $q_1 = q_2 = q$ that we consider, $CS(q_1, q_2) = (1+\gamma) q^2$. Hence, to establish the proposition it suffices to compare the (symmetric) output levels across the four scenarios. Substituting from (8) into (6), the output of each firm under competition is:

$$q^* \equiv \frac{Ar\,(2-\gamma)\,(2+\gamma)}{r\,(2-\gamma)\,(2+\gamma)^2 - 4}.$$

Likewise, substituting from (9) into (6), the output of each firm under sustainability coordination is

$$q^{sc} \equiv \frac{Ar\,(2+\gamma)}{r\,(2+\gamma)^2 - 2}.$$

Under a production cartel, the output levels in Stage 2 are given by (10). Substituting from (11) into (10), the equilibrium output of each firm under the product cartel are given by

$$q^{pc} \equiv \frac{2Ar\,(1-\gamma)}{4r\,(1-\gamma^2) - (2-\gamma)}.$$

Finally, substituting from (12) into (10), each firm's output under full collusion are given by

$$q^{fc} \equiv \frac{Ar}{2r\,(1+\gamma) - 1}.$$

To derive the result, note first that

$$q^* - q^{sc} = \frac{2\gamma Ar\,(2+\gamma)}{\left(r\,(2-\gamma)\,(2+\gamma)^2 - 4\right)\left(r\,(2+\gamma)^2 - 2\right)} > 0,$$

and

$$q^{sc} - q^{fc} = \frac{\gamma Ar\,(r\,(2+\gamma) - 1)}{\left(r\,(2+\gamma)^2 - 2\right)(2r\,(1+\gamma) - 1)} > 0.$$

Hence, $q^* > q^{sc} > q^{fc}$. Moreover,

$$q^{pc} - q^{fc} = \frac{\gamma Ar}{(4r\,(1-\gamma^2) - (2-\gamma))\,(2r\,(1+\gamma) - 1)} > 0.$$

Next, note that

$$q^{sc} - q^{pc} = \frac{2\gamma\,(2-\gamma-\gamma^2)\,Ar\left(r - \frac{4-\gamma}{2(2-\gamma-\gamma^2)}\right)}{(4r\,(1-\gamma^2) - (2-\gamma))\left(r\,(2+\gamma)^2 - 2\right)},$$

where $\frac{4-\gamma}{2(2-\gamma-\gamma^2)}$ is increasing with γ and is equal to 1 when $\gamma = 0$. Hence, $q^{sc} \gtreqless q^{pc}$ as $r \gtreqless \frac{4-\gamma}{2(2-\gamma-\gamma^2)}$. Likewise,

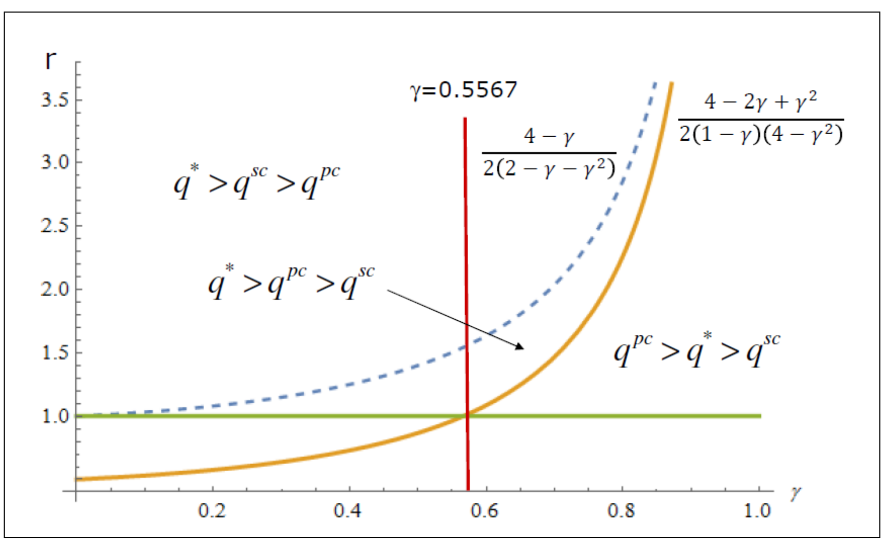
$$q^* - q^{pc} = \frac{2\gamma\,(2-\gamma-\gamma^2)\,Ar\left(r - \frac{4-2\gamma+\gamma^2}{2(1-\gamma)(4-\gamma^2)}\right)}{(4r\,(1-\gamma^2) - (2-\gamma))\left(r\,(2-\gamma)\,(2+\gamma)^2 - 4\right)},$$

where $\frac{4-2\gamma+\gamma^2}{2(1-\gamma)(4-\gamma^2)}$ is increasing with γ and is equal to 1 when $\gamma = 0.5567$. Since by assumption, $r \geq 1$, $q^* > q^{pc}$ for all $\gamma < 0.5567$. When $\gamma > 0.5567$, $q^* \gtreqless v^{pc}$ as $r \gtreqless \frac{4-2\gamma+\gamma^2}{2(1-\gamma)(4-\gamma^2)}$. Finally, note that

$$\frac{4-\gamma}{2\left(2-\gamma-\gamma^2\right)} - \frac{4-2\gamma+\gamma^2}{2\left(1-\gamma\right)\left(4-\gamma^2\right)} = \frac{2}{4-\gamma^2} > 0.$$

Altogether then, $q^* > q^{sc} > q^{pc}$ if $r > \frac{4-\gamma}{2(2-\gamma-\gamma^2)}$, $q^* > q^{pc} > q^{sc}$ if $\frac{4-\gamma}{2(2-\gamma-\gamma^2)} > r > \frac{4-2\gamma+\gamma^2}{2(1-\gamma)(4-\gamma^2)}$, and $q^{pc} > q^* > q^{sc}$ if $r < \frac{4-2\gamma+\gamma^2}{2(1-\gamma)(4-\gamma^2)}$. Finally, note that since $\frac{4-2\gamma+\gamma^2}{2(1-\gamma)(4-\gamma^2)} < 1$ when $\gamma < 0.5567$ and since by construction $r \geq 1$, $q^* > q^{pc}$ for all $\gamma < 0.5567$. ■

Proposition 2 is illustrated in Figure 1 in the (γ, r) space. When r is below the solid curve (but above 1), a production cartel benefits consumers since it induces firms to expand their output level above the level they produce under competition. Clearly, r could be below the solid curve and still above 1 as we have assumed only when $\gamma > 0.5567$. When r is above the solid line, a production cartel hurts consumers, because it leads to lower output levels compared with competition. Still, so long as r is below the dashed curve, consumers are better off under a production cartel than they are under sustainability coordination. When r is above the dashed line, the reverse is true: now consumers are worse off under a production cartel than they are under sustainability coordination.



Illustrating Proposition 2

The results in Proposition 2 are driven by two effects which operate in opposite directions. On the one hand, Proposition 1 shows that a production cartel boosts investments in sustainability, which in turn raises the demand for products and hence induces firms to expand their output. This effect benefits consumers. On the other hand, holding investments in sustainability constant, firms cut output when they form a production cartel, and this effect harms consumers. The first positive effect is particularly large when r is small (i.e., not too much above 1), because as r increases, investment becomes more expensive so firms invest less regardless of whether they collude or not. The first positive effect also becomes larger when γ increases towards 1 because then, the two products become closer substitutes, meaning that absent collusion, competition intensifies. As a result, firms compete away the marginal benefit from investment. But when firms form a production cartel, they get to keep the marginal benefit from investment and hence they have a stronger incentive to invest. Although holding investments in sustainability constant, the second negative effect also becomes larger when γ increases towards 1 (collusion leads to a lower output as competition absent collusion becomes intense), the first positive effect dominates, so firms produce more under a production cartel when r is small and γ is sufficiently close to 1.

As noted, our analysis does not account for the utility of agents who benefit from SCP, but do not actually consume the good in question, like vegetarians in the case of the Chicken of Tomorrow initiative, or future generations in the case of North Sea Shrimps or coal power plants. While our approach is consistent with the principle that consumers in the same relevant market are to be compensated, taking the utility of such individuals into account will only strengthen the case for production cartel and weaken the case for sustainability coordination, since investment in SCP is highest under a production cartel and lowest under sustainability coordination.

We conclude this section by comparing the equilibrium outcomes under the four regimes with the socially optimal outcome. To this end, note that social welfare, defined as the sum of consumer surplus and profits, is given by:

$$W = u + \pi_1 + \pi_2 = (A + v_1)\, q_1 + (A + v_2)\, q_2 - \frac{q_1^2 + q_2^2 + 2\gamma q_1 q_2}{2} - \frac{r v_1^2}{2} - \frac{r v_2^2}{2}. \tag{19}$$

The output and sustainability levels which maximize social welfare are

$$q_1^{**} = q_2^{**} = q^{**} = \frac{Ar}{r(1+\gamma)-1}, \qquad v_1^{**} = v_2^{**} = v^{**} = \frac{A}{r(1+\gamma)-1}.$$

Proposition 3: *$v^{**} \gtreqless v^{pc}$ as $\gamma \lesseqgtr 2/3$. Moreover, $v^{**} > v^{*} > v^{fc} > v^{sc}$.*

Proof: First notice that

$$v^{**} - v^{pc} = \frac{A(2-\gamma-3\gamma^2)\,r}{(r(1+\gamma)-1)\,(4r(1-\gamma^2)-(2-\gamma))},$$

which is positive for $\gamma < 2/3$ and negative for $\gamma > 2/3$. Second, note that

$$v^{**} - v^{*} = \frac{A(4-2\gamma^2-\gamma^3)\,r}{(r(1+\gamma)-1)\left(r(2-\gamma)(2+\gamma)^2-4\right)} > 0.$$

The last part of the proposition follows because $v^{*} > v^{fc} > v^{sc}$ by Proposition 1. ■

Proposition 3 shows that when the two goods are close substitutes in the sense that $\gamma > 2/3$, a production cartel leads to overinvestment in sustainability relative to the socially optimal level. And when $\gamma < 2/3$, firms underinvest in sustainability under all four scenarios. But since investment in sustainability is highest under a production cartel, it is also closer to the socially optimal level, and hence might be welfare enhancing (as Proposition 2 shows whether it is welfare enhancing or not depends on the size of r and γ).

5 The principle of compensation

In accordance with the European Treaty provision that any cartel exemption requires that consumers are allowed a fair share of the resulting benefits, the ACM established in its 2014 vision document on competition and sustainability the so-called 'principle of compensation', which states that one criterion for exempting sustainability initiatives from cartel prohibition is that "consumers on the relevant markets cannot be worse off." (ACM, 2014, p. 11). In this section we examine the effects of this policy on sustainability and consumer welfare, assuming perfect monitoring by the agency.[19]

[19] In reality it may be hard to determine whether consumers are or are not worse off than they would be under competition. See Schinkel and Toth (2016). In what follows we ignore this difficulty and assume that it is possible to compare consumer surplus under collusion with the counterfactual consumer surplus under competition.

As Proposition 2 shows, consumer surplus under sustainability coordination and full collusion is below the level attained absent collusion. To examine how application of the principle of compensation affects the equilibrium under sustainability coordination though, note that under sustainability coordination, firms choose output in Stage 2 noncooperatively, just as they do under competition. In Stage 1, though, they jointly choose levels of sustainability below the competitive levels, i.e., $v^* > v^{sc}$ (see Proposition 1). As the proof of Proposition 2 shows, these lower levels of sustainability induce in Stage 2 output levels which are below q^* (the level attained absent collusion) and hence violate the principle of compensation. To be exempt from cartel prohibition, the two firms are then forced to choose sustainability levels $v_1 = v_2 = v^*$ in Stage 1 to ensure that their resulting output levels in Stage 2 satisfy the principle of compensation. That is, under a sustainability coordination, the principle of compensation ensures that firms would choose the same level of sustainability as in the absence of any coordination.

By contrast, a production cartel may satisfy the principle of compensation when r is sufficiently low, i.e., below the solid line in Figure 1. As Proposition 2 shows, this occurs when $1 \leq r < \frac{4-2\gamma+\gamma^2}{2(1-\gamma)(4-\gamma^2)}$, which is feasible only when $\gamma > 0.5567$. By the principle of compensation, firms can safely form a production cartel in this case without changing their behavior; hence the equilibrium sustainability level remain equal to v^{pc}.

When r is above the solid line in Figure 1, i.e., $r > \frac{4-2\gamma+\gamma^2}{2(1-\gamma)(4-\gamma^2)}$, a production cartel lowers consumer surplus below the level attained absent collusion. To be exempt from cartel prohibition, the two firms must then choose their output levels in Stage 2 to maximize the sum of their profits subject to the constraint that $CS(q_1, q_2) \geq CS(q^*, q^*)$, where q^* is the output levels absent collusion. If we restrict attention to symmetric solutions, where $q_1 = q_2 = q$, the constraint implies that

$$(1+\gamma)\, q^2 \geq (1+\gamma)\,(q^*)^2\,, \qquad \Longrightarrow \qquad q \geq q^* = \frac{Ar\,(2-\gamma)\,(2+\gamma)}{r\,(2-\gamma)\,(2+\gamma)^2 - 4}. \tag{20}$$

That is, output is at least as high as in a Nash equilibrium absent collusion.

When constraint (20) is binding, which happens when r is above the solid curve in Figure 1, each firm must produce q^* in order to ensure cartel exemption. The profit of each firm $i = 1, 2$, when $q_1 = q_2 = q^*$, is given by

$$\pi_i = (A + v_i - (1+\gamma)\, q^*)q^* - \frac{rv_i^2}{2}, \tag{21}$$

where $A \equiv a - k$. Note that π_i is independent of the rivals's level of sustainability. The value of v_i which maximizes π_i is

$$v^E = \frac{q^*}{r} = \frac{A\,(2-\gamma)\,(2+\gamma)}{r\,(2-\gamma)\,(2+\gamma)^2 - 4},$$

where superscript E stands for "exemption."

Using (8), it follows that

$$\begin{aligned} v^* - v^E &= \frac{4A}{r\,(2-\gamma)\,(2+\gamma)^2 - 4} - \frac{A\,(2-\gamma)\,(2+\gamma)}{r\,(2-\gamma)\,(2+\gamma)^2 - 4} \\ &= \frac{4A\,(1-\gamma^2)}{r\,(2-\gamma)\,(2+\gamma)^2 - 4} > 0. \end{aligned}$$

Hence, application of the principle of compensation induces firms, when they form a production cartel, to lower their investments in sustainability, relative to the level they choose absent collusion. Since Proposition 1 implies that $v^* < v^{pc}$, it also follows that $v^E < v^* < v^{pc}$: the principle of compensation induces firms to invest in sustainability less than they do either absent collusion or under a production cartel without the principle of compensation.

Proposition 4: *Imposing the principle of compensation, which exempts firms from cartel prohibition when consumers are at least as well off as in the absence of collusion, has the following implications:*

(i) *Under sustainability coordination, the principle of compensation ensures that firms would choose the same level of sustainability and consumers would get the same level of utility as in the absence of collusion.*

(ii) *Under a production cartel, the principle of compensation has no bite if $r < \frac{4-2\gamma+\gamma^2}{2(1-\gamma)(4-\gamma^2)}$; in equilibrium, both firms continue to invests $v^{pc} > v^*$ and consumers are better off under the cartel than they are absent collusion. By contrast, if $r > \frac{4-2\gamma+\gamma^2}{2(1-\gamma)(4-\gamma^2)}$ (which is surely the case when $\gamma < 0.5567$), then the principle of compensation induces firms to choose sustainability level v^E, such that $v^E < v^* < v^{pc}$; consumers however get the same utility as in the absence of collusion.*

Proposition 4 shows that the principle of compensation ensures that sustainability coordination has no effect on consumers nor on sustainability. In the case of a production cartel under which consumers are better off, constraint (20) is non binding, so the principle of compensation has no bite. In that case, since $v^{pc} > v^*$, a production cartel continues to boost investments in sustainability. However, when constraint (20) is binding, the principle of compensation ensures that the cartel cannot harm consumers, but now it induces firms to cut their investments in sustainability.

To see why, note from (21) that when constraint (20) is binding, investment in sustainability only affects the firm's profit directly, but it no longer affects it indirectly through the output levels, which are now set at q^* to ensure cartel exemption. The first order condition for v^E is then given by $\frac{\partial \pi_1}{\partial v_2} = 0$ (the same holds for firm 2). Now, evaluating the first order condition for v_1^* (equation (14)) at v^E, yields,

$$\left.\frac{\partial \pi_1}{\partial v_1}\right|_{v_1 = v^E} = \frac{\partial \pi_1}{\partial q_2}\frac{\partial q_2^*\left(v^E, v^E\right)}{\partial v_1} + \underbrace{\frac{\partial \pi_1}{\partial v_1}}_{=0} \geq 0,$$

where the inequality follows because $\frac{\partial \pi_1}{\partial q_2} < 0$ and $\frac{\partial q_2^*\left(v^E, v^E\right)}{\partial v_1} < 0$. Hence, $v^E < v^*$. Since $v^* < v^{pc}$, we get $v^E < v^* < v^{pc}$.

Intuitively, absent collusion, firms invest in Stage 1 not only in order to boost the demand for their respective products, but also for strategic reasons: higher sustainability makes the firm's product more attractive relative to the rival's product, and hence induces the rival to cut its output level in Stage 2. This extra incentive to invest disappears when the principle of compensation applies, because then firms are forced to expand their output levels anyway in period 2 to ensure that the cartel does not harm consumers and hence sustainability does not affect output anymore in Stage 2. In sum, the analysis shows that whenever the compensation principle is needed to assure that consumers receive their fair share of the sustainability benefits, the requirement lowers investments in SCP below their level under competition.

6 Concluding remarks

We examined the conditions under which allowing firms to coordinate their actions may promote investments in SCP and potentially benefit consumers. We showed that when consumers are willing to pay extra for sustainable products and firms chose their investment in sustainability before choosing output, allowing firms to coordinate their investment levels (sustainability coordination) leads to lower investments in SCP and a lower consumer surplus relative to the no coordination case. By contrast, allowing firms to coordinate their output levels (or prices) but not their investments (production cartel), leads to higher investments in SCP and may even benefit consumers. In essence, when firms coordinate their production, they do not compete away the benefits from investments, and therefore have a stronger incentive to invest in SCP in the first place. Although collusion leads to lower output levels for a given level of investments in SCP, the fact that it boosts these investments, and thereby the willingness of consumers to pay, means that firms eventually produce more under a production cartel. Our analysis reveals that when the marginal cost of investment is relatively low and the two products are sufficiently close substitutes, the higher investment in SCP also implies a higher consumer surplus. These results are quite general as they are not driven by the specific functional forms we use, and they also extend to price competition, repeated interaction, and investment spillovers (provided the spillovers are not too large).

Our findings stand in stark contrast to the emerging policies, which primarily consider the exemption of horizontal agreements that involve investments in sustainability, but not price or quantity coordination. We show that this approach leads to worse outcomes than a complete prohibition of horizontal agreements. We also show that making the exemption from cartel prohibition conditional on consumers being at least as well off as they are absent collusion does not improve matters, because the resulting outcome in this case is either identical to, or even worse than that absent collusion. Hence, our analysis suggests that sustainability coordination is a poor idea. This is all the more so given that in reality it may be very hard for a competition authority to determine whether consumer welfare under sustainability coordination is the same as under the counterfactual case absent collusion.

An obvious alternative to competition policy as a way to promote SCP, is to use traditional regulation. For example, it might be possible to protect fisheries by banning fishing methods that damage the seabed, and it might be possible to improve the living conditions of broilers by imposing minimum quality standards on broiler farmers. The drawback of government regulation is that designing effective regulation is a complex task and the government may lack the needed information to do it effectively. Although self-regulation in the form of sustainability coordination overcomes these drawbacks, our analysis shows that it distorts the standards which are being set as well as the output levels of firms.

Our analysis should be viewed as a first step towards understanding the trade-offs involved with the use of competition policy to promote SCP. For example, we abstract from the way asymmetric firms choose output levels under a production cartel when they cannot rely on side payments, we do not model the explicitly actions of the antitrust authority, and we implicitly assume that the antitrust authority can perfectly determine if firms collude and if collusion benefits or harms consumers. We also abstract from wider policy considerations, such as whether horizontal agreements are actually necessary to promote SCP or whether there are better way of doing that. We believe that these questions, as well as others, should be further explored in future research to develop a better understanding of whether competition policy should be used to promote SCP, and if so how exactly.

7 Appendix

In the main text of the paper, we assumed that firms can fully coordinate their sustainability levels, or output choices, or both. While the horizontal agreements which we consider would be exempt from antitrust liability and therefore not illicit, one may wonder whether they are also self-enforcing, i.e., incentive compatible. To address this question, we will assume that the two firms interact repeatedly in the market over infinitely many periods. Two ways to model this situation immediately come to mind.

One approach is to assume that firms choose their sustainability levels, v_1 and v_2, once and for all at the outset and then repeatedly choose their output levels, q_1 and q_2. However, with this approach, sustainability coordination cannot be made incentive compatible, because firms choose v_1 and v_2 only once at the outset and then repeatedly choose the

Nash equilibrium quantities in every stage game. As a result, firms cannot punish each other for deviations from a collusive agreement on v_1 and v_2.

A second approach is to assume that the two-stage game (firms first choose v_1 and v_2 and then choose q_1 and q_2) is infinitely repeated. The problem with this approach is that when γ is large and r is not too large, the profits under a production cartel are lower than the profits under competition in both stages.[20] As a result, firms will not engage in a production cartel under this setting, unless γ is small and r is large.

Our approach then is a hybrid of the two approaches: in period $t = 1$, firms first choose v_1 and v_2 and then choose q_1 and q_2. Then in every period $t > 1$, the choices of v_1 and v_2 from period $t - 1$ stay in place with probability ρ, and firms only need to choose q_1 and q_2. However with probability $1 - \rho$, firms need to choose v_1 and v_2 from scratch before choosing q_1 and q_2. This setting reflects the idea that sustainability is embodied in the firms' production facilities which, with probability $1-\rho$, may become obsolete or need to be replaced due to a new regulation or to some negative external shock. In what follows, we will focus on collusive agreements which are supported by trigger strategies: firms collude, but following a deviation from collusion, both firms begin to play the Nash equilibrium in all periods.

7.1 Production cartel

Under a production cartel, the two firms jointly choose the collusive output levels $q_1^{pc}(v_1, v_2)$ and $q_2^{pc}(v_1, v_2)$, given v_1 and v_2, and then earn the collusive profits $\pi_1^{pc}(v_1, v_2)$ and $\pi_2^{pc}(v_1, v_2)$. The collusive agreement stays in place until one or both firms deviate from the agreement, or until the two firms need to choose v_1 and v_2 from scratch (firms may then reach a new collusive agreement given the new choices of v_1 and v_2). When firm 1, say, deviates unilaterally from the collusive agreement, its deviation profit is

$$\pi_1^d(v_1, v_2) \equiv \pi_1\left(BR_1\left(q_2^{pc}(v_1, v_2)\right), q_2^{pc}(v_1, v_2), v_1, v_2\right),$$

[20] This result is consistent with Gandal and Fershtman (1994) showing that semicollusion, i.e., competition in a first stage (say R&D or capacity choices), followed by collusion in the product market, may be unprofitable. In their model though, products are homogenous rather than differentiated as in our paper and firms may differ in their cost functions if they make different choices in the first stage of the game.

where $BR_1\left(q_2^{pc}\left(v_1, v_2\right)\right)$ is firm 1's best response against $q_2^{pc}\left(v_1, v_2\right)$. Firm 2's deviation profit is equivalent. Following the deviation period, the two firms choose the Nash equilibrium output levels and earn $\pi_1\left(v_1, v_2\right)$ and $\pi_2\left(v_1, v_2\right)$ until they need to choose v_1 and v_2 again from scratch (the profit functions are defined by (7)). After choosing new levels of v_1 and v_2, the two firms may reach a new collusive agreement.

Using δ to denote the intertemporal discount factor, a pair of collusive output levels, $q_1^{pc}\left(v_1, v_2\right)$ and $q_2^{pc}\left(v_1, v_2\right)$, is incentive compatible for firm 1 provided that

$$\frac{\pi_1^{pc}\left(v_1, v_2\right)}{1-\rho\delta} \geq \pi_1^d\left(v_1, v_2\right) + \frac{\rho\delta\pi_1\left(v_1, v_2\right)}{1-\rho\delta},$$

or

$$\pi_1^{pc}\left(v_1, v_2\right) \geq \left(1-\rho\delta\right)\pi_1^d\left(v_1, v_2\right) + \rho\delta\pi_1\left(v_1, v_2\right). \tag{22}$$

The incentive compatibility condition for firm 2 is equivalent. Note that $\rho\delta$ is the effective discount factor. Condition (22) surely holds when $\rho\delta$ approaches 1, since by revealed preferences, $\pi_1^{pc}\left(v_1, v_2\right) \geq \pi_1\left(v_1, v_2\right)$ for all v_1 and v_2 (firms can always agree to collude on the Nash equilibrium output levels if this is more profitable).

7.2 Sustainability coordination

Here the two firms jointly choose the sustainability levels v_1^{sc} and v_2^{sc} first and then choose the Nash equilibrium output levels given v_1^{sc} and v_2^{sc}. The resulting collusive profits are $\pi_1\left(v_1^{sc}, v_2^{sc}\right)$ and $\pi_2\left(v_1^{sc}, v_2^{sc}\right)$. On the collusive path, the two firms continue to choose v_1^{sc} and v_2^{sc} whenever they need to choose v_1 and v_2 from scratch and hence they earn $\pi_1\left(v_1^{sc}, v_2^{sc}\right)$ and $\pi_2\left(v_1^{sc}, v_2^{sc}\right)$ in every period. If firm 1, say, deviates unilaterally, its one stage deviation profit is $\pi_1\left(BR_1\left(v_2^{sc}\right), v_2^{sc}\right)$, where $BR_1\left(v_2^{sc}\right)$ is firm 1's best response against v_2^{sc}. Firm 1 continues to earn $\pi_1\left(BR_1\left(v_2^{sc}\right), v_2^{sc}\right)$ so long as v_1 and v_2 are in place. Once firms need to choose v_1 and v_2 from scratch, they choose the Nash equilibrium sustainability levels v_1^* and v_2^* in all future profits and their resulting profits become $\pi_1\left(v_1^*, v_2^*\right)$.

To compute the expected discounted sum of firm 1's profits following a deviation, let

$$V_1^d = \pi_1\left(BR_1\left(v_2^{sc}\right), v_2^{sc}\right) + \delta\rho V_1^d + \delta\left(1-\rho\right)V_1^*,$$

and

$$V_1^* = \pi_1(v_1^*, v_2^*) + \delta V_1^*,$$

be the value functions of firm 1 following a deviation from v_1^{sc}, starting from a period in which the sustainability levels are $BR_1(v_2^{sc})$ and v_2^{sc} (with probability ρ the sustainability levels remain in place and the value next period remains V_1^d and with probability $1-\rho$ the sustainability levels are chosen from scratch) and starting from a period in which v_1 and v_2 are chosen from scratch (firms then earn the Nash equilibrium profit, $\pi_1(v_1^*, v_2^*)$, in all periods). Solving the two equations yields

$$V_1^d = \frac{\pi_1(BR_1(v_2^{sc}), v_2^{sc}) + \delta(1-\rho)\frac{\pi_1(v_1^*, v_2^*)}{1-\delta}}{1-\delta\rho}, \qquad V_1^* = \frac{\pi_1(v_1^*, v_2^*)}{1-\delta}.$$

Given V_1^d, a collusive pair, v_1^{sc} and v_2^{sc}, is incentive compatible for firm 1 provided that

$$\frac{\pi_1(v_1^{sc}, v_2^{sc})}{1-\delta} \geq \frac{\pi_1(BR_1(v_2^{sc}), v_2^{sc}) + \delta(1-\rho)\frac{\pi_1(v_1^*, v_2^*)}{1-\delta}}{1-\delta\rho},$$

or

$$(1-\delta\rho)\pi_1(v_1^{sc}, v_2^{sc}) \geq (1-\delta)\pi_1(BR_1(v_2^{sc}), v_2^{sc}) + \delta(1-\rho)\pi_1(v_1^*, v_2^*). \tag{23}$$

The incentive compatibility condition for firm 2 is equivalent. When δ approaches 1, (23) surely holds since by revealed preferences, $\pi_1(v_1^{sc}, v_2^{sc}) \geq \pi_1(v_1^*, v_2^*)$ (firms can always agree to collude on the Nash equilibrium sustainability levels).

7.3 Full collusion

Under collusion in both stage, the two firms jointly choose the collusive sustainability levels, v_1^{fc} and v_2^{fc}, and then choose the output levels $q_1^{pc}\left(v_1^{fc}, v_2^{fc}\right)$ and $q_2^{pc}\left(v_1^{fc}, v_2^{fc}\right)$ and earn $\pi_1^{pc}\left(v_1^{fc}, v_2^{fc}\right)$ and $\pi_2^{pc}\left(v_1^{fc}, v_2^{fc}\right)$ in every period (the output levels and profits are the same as under production cartel, except that now the choice of v_1 and v_2 is also collusive). The collusive agreement stays in place until one or both firms deviate either by choosing a different output level or a different sustainability level. When firm 1, say, deviates unilaterally from the collusive output level, its deviation profit is

$$\pi_1^d\left(v_1^{fc}, v_2^{fc}\right) \equiv \pi_1\left(BR_1\left(q_2^{pc}\left(v_1^{fc}, v_2^{fc}\right)\right), q_2^{pc}\left(v_1^{fc}, v_2^{fc}\right), v_1^{fc}, v_2^{fc}\right),$$

where $BR_1\left(q_2^{pc}\left(v_1^{fc}, v_2^{fc}\right)\right)$ is firm 1's best response against $q_2^{pc}\left(v_1^{fc}, v_2^{fc}\right)$. Firm 2's deviation profit is equivalent. Following the deviation period, and so long as v_1^{fc} and v_2^{fc} are still in place, the two firms choose the Nash equilibrium output levels, $q_1^*\left(v_1^{fc}, v_2^{fc}\right)$ and $q_2^*\left(v_1^{fc}, v_2^{fc}\right)$ given v_1^{fc} and v_2^{fc}, and their profits are $\pi_1\left(v_1^{fc}, v_2^{fc}\right)$ and $\pi_2\left(v_1^{fc}, v_2^{fc}\right)$. And, when the two firms need to choose v_1 and v_2 from scratch, they choose the Nash equilibrium sustainability levels v_1^* and v_2^* forever after and their resulting profits become $\pi_1(v_1^*, v_2^*)$ and $\pi_2(v_1^*, v_2^*)$.

To show conditions under which full collusion is incentive compatible, we must show the conditions under which it does not pay firms to deviate from the collusive agreement either when they choose quantities or when they choose sustainability levels. We start with deviations from the collusive output levels. To this end, let

$$V_1^d = \pi_1^d\left(v_1^{fc}, v_2^{fc}\right) + \delta\rho V_1^d + \delta(1-\rho)V_1^*,$$

and

$$V_1^* = \pi_1(v_1^*, v_2^*) + \delta V_1^*,$$

be firm 1's value functions following a deviation from $q_1^{pc}\left(v_1^{fc}, v_2^{fc}\right)$, starting from a period in which the sustainability levels are v_1^{fc} and v_2^{fc} and starting from a period in which v_1 and v_2 are chosen from scratch. Solving the two equations yields

$$V_1^d = \frac{\pi_1^d\left(v_1^{fc}, v_2^{fc}\right) + \delta(1-\rho)\frac{\pi_1(v_1^*, v_2^*)}{1-\delta}}{1-\delta\rho}, \qquad V_1^* = \frac{\pi_1(v_1^*, v_2^*)}{1-\delta}.$$

Given V_1^d, firm 1 does not wish to deviate from $q_1^{pc}\left(v_1^{fc}, v_2^{fc}\right)$ provided that

$$\frac{\pi_1\left(v_1^{fc}, v_2^{fc}\right)}{1-\delta} \geq \frac{\pi_1^d\left(v_1^{fc}, v_2^{fc}\right) + \delta(1-\rho)\frac{\pi_1(v_1^*, v_2^*)}{1-\delta}}{1-\delta\rho},$$

or

$$(1-\delta\rho)\pi_1\left(v_1^{fc}, v_2^{fc}\right) \geq (1-\delta)\pi_1^d\left(v_1^{fc}, v_2^{fc}\right) + \delta(1-\rho)\pi_1(v_1^*, v_2^*). \qquad (24)$$

The incentive compatibility condition for firm 2 is equivalent. When δ approaches 1, condition (24) holds, since by revealed preferences, $\pi_1\left(v_1^{fc}, v_2^{fc}\right) \geq \pi_1(v_1^*, v_2^*)$ (firms can always agree to collude on the Nash equilibrium sustainability and quantity levels).

Finally, note that the condition that ensures that full collusion is immune to deviations when choosing sustainability levels is similar to the condition that ensures that sustainability coordination is incentive compatible, except that v_1^{fc} and v_2^{fc} replace v_1^{sc} and v_2^{sc}:

$$(1-\delta\rho)\,\pi_1\left(v_1^{fc},v_2^{fc}\right) \geq (1-\delta)\,\pi_1\left(BR_1\left(v_2^{fc}\right),v_2^{fc}\right)+\delta\,(1-\rho)\,\pi_1\left(v_1^*,v_2^*\right). \tag{25}$$

When δ approaches 1, condition (25) coincides with condition (24) and hence holds as well.

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