Green Collusion, Sustainability and Welfare*

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June 13, 2024

Abstract

We develop a model of oligopoly to analyze the desirability of sustainable agreements and uncover the circumstances under which green collusion should be allowed by competition authorities. Our model encompasses emissions taxation by a regulatory agency and extends to product differentiation when consumers value sustainable products more. Moreover, we show that cross-ownership may partially imitate the effects of sustainable horizontal agreements on the adoption of greener technologies.

JEL Classification: D43; L13; L21; Q52; Q56.

Keywords: Sustainable agreements; Collusion; Competition.

PRELIMINARY VERSION - WORK IN PROGRESS

*We wish to thank seminar participants at the Dipartimento di Scienze economiche e aziendali of the University of Sassari, the Dipartimento di Giurisprudenza, Economia e Scienze Umane of the University Mediterranea di Reggio Calabria, the CEREB Colloquium, University of Erfurt and the OLIGO2024 workshop in Crete, for valuable comments and suggestions.

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1 Introduction

The climate crisis has lead many countries to reconsider their policies towards environmental protection, see OECD (2020, 2021, 2023). When production generates pollution, in general the market mechanism is incapable of inducing allocations that are environmentally friendly. Investing on reducing pollution is costly, it usually increases the marginal cost of production and reduces output. In the presence of a regulatory agency that taxes pollution, firms are incentivised to invest in greener technologies so as to decrease the emission tax burden without shrinking their production levels. Besides taxation considerations, firms may have incentives to invest in green or sustainable products as long as consumers value these products more than the conventional ones, see Köveker et al. (2023). Either way, in the context of oligopolistic competition, the incentives to adopt greener technologies depend on the choices of rivals.[1]

If a firm goes green, without any taxation or demand side benefit, it suffers a cost disadvantage that is exploited by its competitors. Moreover in the presence of spillover effects, the polluting firm may be able to pollute even more when its green competitors pollute less. However when firms enjoy tax benefits from reducing product related pollution or demand side benefits from producing more sustainable products, they find themselves in prisoner's dilemma situation: coordination on adopting a green technology may induce higher profits for all firms and less pollution, however such coordination may realize only through a binding agreement which is often forbidden or viewed with suspicion by competition authorities.

Schinkel and Spiegel (2017) provide many examples of green agreements. For instance, in June 2022, the Dutch Authority for Consumers & Markets (ACM) accepted a collaboration that enabled Competitors Shell and TotalEnergies to collaborate on capturing, transporting, and storing carbon dioxide in empty gas fields in the North Sea. In 2000, washing machine manufacturers which hold in excess of 95% of the EU market agreed to

[1]For more in this literature see Inderst, Sartzetakis, and Xepapadeas (2023); Lambertini, Poyago-Theotoky, and Tampieri (2017); Malinauskaite (2022); Ouchida and Goto (2022); Strandholm, Espinola-Arredondo, and Munoz-Garcia (2024)

stop producing for and importing into the EU machines labelled under energy categories D to G. In 2014 dutch supermarkets, broiler farmers, and broiler meat processors made arrangements to produce meat under enhanced animal friendly conditions (Chicken of Tomorrow case). In July 2019, the State of California and four car manufacturers entered into a California Air Resources Board framework agreement to lower the average fuel consumption and average emissions. DoJ opened investigation for cartel but did not press any charges.

In June 2023, the Guidelines to Horizontal Cooperation Agreements (2023/c 259/01) make explicit reference to "Sustainability Agreements" Article 519 says "However, one concern related to sustainable development is that individual production and consumption decisions can have negative effects ('negative externalities'), for example on the environment, that are not sufficiently taken into account by the economic operators or consumers that cause them. This type of market failure can be mitigated or cured by collective action, primarily through public policies or (sector-specific) regulation, and secondarily through cooperation agreements between undertakings that promote sustainable production or consumption." Also in article 521, "...the term *sustainability agreement* refers to any horizontal cooperation agreement that pursues a sustainability objective, irrespective of the form of the cooperation. Sustainability agreements will only raise competition concerns under Article 101 if they entail restrictions of competition... Agreements that restrict competition cannot escape the prohibition laid down in Article 101(1) simply by referring to a sustainability objective" and article 522 concludes "...Where sustainability agreements restrict competition within the meaning of Article 101(1), they may still be compatible with Article 101 if they fulfil the four conditions of the exception provided by Article 101(3), ...(OJ C 101, 27.4.2004, p. 97) "Agreements that restrict competition may at the same time have pro-competitive effects by way of efficiency gains... *When the pro-competitive effects of an agreement outweigh its anti-competitive effects the agreement is on balance pro-competitive and compatible with the objectives of the Community competition rules.*"

The basic research goal of this paper is to show under which conditions should competition authorities allow green horizontal agreements so as to foster sustainable production and consumption. We develop a model of oligopoly to explain the circumstances under which the pro-competitive effects of a sustainable agreement (green collusion) may outweigh its anti-competitive effects. Our model comprises both public intervention in the form of taxation of pollution, but also product market and green collusion.

Our results provide theoretical support for allowing sustainable agreement. We derive simple conditions on the desirability of green collusion that depend on the cost of green investment and the severity of environmental damage of production.

The remainder of the paper is organized as follows. Section 2 describes the model. Section 3 characterizes the equilibrium outcomes. Section 4 discusses the results. Section 5 provides extensions and section 6 concludes.

2 The Model

We consider an homogeneous-good duopoly based on Poyago-Theotoky (2007). Firm 1 and 2 pollute and face a per unit emissions fee by a regulatory agency. There is a 1-1 relationship between production and emissions, therefore firms may reduce emissions either by producing less or by investing in green technology which is costly.

2.1 Firms

Firms face the following inverse demand function:

$$p(q_i, q_j) = a - q_1 - q_2$$

where $a > 0$.

The profit function of a firm $i = 1, 2$ is:

$$\pi_i(q_i, q_j, z_i, z_j) = p(q_i, q_j)q_i - cq_i - t(q_i - z_i) - \frac{1}{2}\gamma(z_i)^2,$$

where q_i is the output, with the index $j = 1, 2, j \neq i$ denoting the the rival's choice, $c > 0$

is the constant marginal cost of production such that $a > c$, t is the per unit emissions fee which is imposed on the total emissions of firm i, $e_i \equiv q_i - z_i$. We assume that each unit of output produces one unit of emission, but emissions can be reduced if a firm invests $z_i \geq 0$ units in green technology. It may be thought of as an "end-of-pipe" filter that neutralizes one unit of air pollution caused by the production of one unit of output. The total cost on investment in green technology (or abatement cost) is $\gamma(z_i)^2/2$ where $\gamma > 0$ is a cost coefficient of abatement.

Given the output and abatement decisions, the total Environmental Damage (ED) caused by production is

$$ED = d\sum_i (q_i - z_i)^2$$

where $d > 1/2$ is a coefficient of severity of environmental damage.

2.2 The Regulatory Agency

The Regulatory Agency (RA) chooses $t \geq 0$ so as to maximize total welfare W defined as

$$W = CS + PS + T - ED,$$

where $CS = \frac{(\alpha-p)}{2}\sum_i q_i$ is consumer surplus, $PS = \sum_i \pi_i$ is producer surplus, $T = t\sum_i (q_i - z_i)$ is the tax revenue from the fees imposed on emissions. We assume as in Strandholm, Espinola-Arredondo, and Munoz-Garcia (2023) that the regulatory agency cannot commit to the emission fee. The latter is set to maximize social welfare after it observes the emissions levels by firms.

2.3 The Game

We build a three stage model where we allow firms to make green investments in the first stage either independently, by taking as given the investment level of the rival (as in Cournot competition), or jointly by coordinating on the level of investment that maximizes total industry profits (as a cartel). Similarly for output choices in the third stage firms may play Cournot or Cartel.

The timing of the game is the following.

Stage 1: Each firm i chooses its investment in green technology, z_i, i) either by taking as given the investment level of the rival firm z_j so as to maximize π_i (Cournot) or ii) jointly with the rival firm j so as to maximize joint profits $\pi_i + \pi_j$ (Cartel).

Stage 2: The RA chooses the per unit emissions fee t to maximize total welfare W.

Stage 3: Each firm i observes z_j and t and chooses its quantity q_i iii) either by taking as given q_j (Cournot) so as to maximize π_i or iv) jointly with its rival so as to maximize joint profits $\pi_i + \pi_j$ (Cartel).

The game described above produces four possible variations arising from the mode of competition in stages one and three:

1. **Cournot-Cournot** (competition) for i) Cournot in stage one and iii) Cournot in stage three,

2. **Cartel-Cournot** (semi-collusion) for ii) Cartel in stage one and iii) Cournot in stage three,

3. **Cournot-Cartel** (semi-collusion) for i) Cournot in stage one and iv) Cartel in stage three,

4. **Cartel-Cartel** (full-collusion) for ii) Cartel in stage one and iv) Cartel in stage three.

We calculate the subgame perfect Nash equilibrium for the above four variations of the game.

3 Equilibria

3.1 Competition in green investment and output (Cournot-Cournot)

We use SPNE to solve the model with backward induction.

Stage 3: Each firm i observes z_j and t and chooses its quantity, q_i taking as given q_j (Cournot) so as to maximize π_i.

$$q_1 = q_2 = (a - c - t)/3$$

Stage 2: The RA chooses the per unit emissions fee t to maximize total welfare W.

$$t = \frac{c - 4cd + a(4d - 1) - 6d(z_1 + z_2)}{2 + 4d}$$

Stage 1: Each firm i chooses its investment in green technology, z_i, taking as given the investment level of the rival firm z_j so as to maximize π_i.

$$z_1 = z_2 = \frac{(a - c)(4d + 8d^2 - 1)}{2[\gamma + d(9 + 14d + 4(1 + d)\gamma)]}$$

From the reactions functions $z_i(z_j)$ we deduce that z_i and z_j are strategic substitutes, i.e $dz_i/dz_j < 0$.

The equilibrium values are the following.

Profits

$$\pi_1^{CC}(\gamma, d) = \pi_2^{CC}(\gamma, d) = \frac{2d(1 + 3d)[3 + 8d(3 + 4d)] + A}{8[\gamma + d(9 + 14d + 4(1 + d)\gamma)]^2}(a - c)^2$$

where $A = \gamma + 8d[3 + d(9 + 4d(3 + 2d))]\gamma + 2(\gamma + 2d\gamma)^2$

Welfare

$$W^{CC}(\gamma, d) = \frac{2d(5d(1 + 2d)(13 + 16d) - 2) + B}{4[\gamma + d(9 + 14d + 4(1 + d)\gamma)]^2}(a - c)^2$$

where $B = 4d(1 + 2d)(3 + 2d)(3 + 4d) - 1)\gamma + 2(1 + 2d)^3\gamma^2$

Enviromental Damage

$$ED^{CC}(\gamma, d) = \frac{d[1 + \gamma + d(3 + 2\gamma)]^2}{[\gamma + d(9 + 14d + 4(1 + d)\gamma)]^2}(a - c)^2$$

Consumer Surplus

$$CS^{CC}(\gamma,d)=\frac{[\gamma+d(7+8d+2\gamma)]^2}{2[\gamma+d(9+14d+4(1+d)\gamma)]^2}(a-c)^2$$

3.2 Collusion in green investment and output competition (Cartel-Cournot)

Stage 3 (Cournot competition) and **stage 2** (choice of emission tax rate) are the same as before

In **stage 1**, firms collude and choose z_1, z_2 so that they maximize joint profits $\Pi = \pi_1 + \pi_2$

$$\begin{aligned}\max_{z_1,z_2}\Pi(z_1,z_2) &= [p(z_1,z_2)-c](q_1(z_1,z_2)+q_2(z_1,z_2)) \\ &\quad -t[q_1(z_1,z_2)+q_2(z_1,z_2)-z_1-z_2] \\ &\quad -\frac{1}{2}\gamma[(z_1)^2+(z_2)^2]\end{aligned}$$

As before we use backward induction to calculate equilibrium values at the SPNE for **Cartel-Cournot (KC)** $\pi_i^{KC}(\gamma,d), W^{KC}(\gamma,d), ED^{KC}(\gamma,d), CS^{KC}(\gamma,d)$

3.3 Green Competition and Product Market Collusion (Cournot-Cartel)

In **Stage 3** firms collude (product market Cartel) and choose q_1, q_2 so as to maximize joint profits $\Pi = \pi_1 + \pi_2$

$$\begin{aligned}\max_{q_1,q_2}\Pi(q_1,q_2) &= (p-c)(q_1+q_2)-t(q_1+q_2-z_1-z_2) \\ &\quad -\frac{1}{2}\gamma[(z_1)^2+(z_2)^2]\end{aligned}$$

which leads to $q_1 = q_2 = (a-c-t)/4$.

In **stage 2 and 1** same as the basic model. With backward induction we obtain the values at the SPNE for Cournot-Cartel (CK)

$$\pi_i^{CK}(\gamma, d), W^{CK}(\gamma, d), ED^{CK}(\gamma, d), CS^{CK}(\gamma, d)$$

3.4 Green Collusion and Product Market Collusion (Cartel-Cartel)

In **Stage 3** firms collude (product market Cartel) and choose q_1, q_2 so as to maximize joint profits $\Pi = \pi_1 + \pi_2$

$$\begin{aligned}\max_{q_1,q_2} \Pi(q_1, q_2) &= (p-c)(q_1+q_2) - t(q_1+q_2-z_1-z_2) \\ &\quad -\frac{1}{2}\gamma[(z_1)^2 + (z_2)^2]\end{aligned}$$

which leads to $q_1 = q_2 = (a-c-t)/4$.

In **stage 2** same as the basic model. In **stage 1**, firms collude and choose z_1, z_2 so that they maximize joint profits $\Pi = \pi_1 + \pi_2$

$$\max_{z_1,z_2} \Pi(z_1, z_2)$$

With backward induction we obtain the values at the SPNE for Cartel-Cartel (KK)

$$\pi_i^{KK}(\gamma, d), W^{KK}(\gamma, d), ED^{KK}(\gamma, d), CS^{KK}(\gamma, d)$$

4 Results

We compare and rank the equilibrium values of the game variations analysed in the previous sections. We use superscript letters K to denote Cartel and C for Competition in chronological order, for example KC (CK) denotes Cartel (resp. Cournot) in the first stage and Cournot (resp. Cartel) in the third stage. We obtain the following rankings

$$\begin{aligned}
W^{KC} &\gtrless W^{CC} > W^{KK} > W^{CK}, \\
Z^{KC} &\gtrless Z^{CC} > Z^{KK} > Z^{CK}, \\
Q^{KC} &\gtrless Q^{CC} > Q^{KK} > Q^{CK}, \\
t^{KC} &\gtrless t^{CC} > t^{CK} > t^{KK}, \\
EM^{CK} &> EM^{KK} > EM^{CC} \gtrless EM^{KC}, \\
T^{CK} &> T^{KK} > T^{CC} \gtrless T^{KC}, \\
ED^{CK} &> ED^{KK} > ED^{CC} \gtrless ED^{KC}, \\
PS^{KK} &> PS^{CK} > PS^{KC} > PS^{CC}, \\
\pi^{iKK} &> \pi^{iCK} > \pi^{iKC} > \pi^{iCC},
\end{aligned}$$

which lead to the following lemma.

Lemma 1. *Green collusion may be Pareto superior to competition. Coordination in green investment can be welfare improving, lead to more green investment, less environmental damage, more profit and higher consumer surplus.*

Proof. See the appendix. □

In particular if $d > \gamma$ and $d < \frac{3+2\gamma}{4}$, then $W^{KC} > W^{CC}$. Horizontal green agreements are welfare improving. The intuition is the following: when the coefficient of abatement cost is not too high and the environmental damage of production is relatively lower compared to the abatement cost, green collusion is profitable because it increases output at a lower environmental cost due to higher green investment.

Lemma 2. *Lemma 1 holds also with Stackelberg Competition in the first stage (Going green first)*

Proof. See the appendix. □

5 Extensions

5.1 Partial Cross-Ownership

Suppose each firm has a non controlling share $s < 1/2$ in the other firm (cross-ownership). Then the managers problem is to maximize

$$
\begin{aligned}
V_1 &= (1-s)\pi_1 + s\pi_2 \propto \pi_1 + \lambda\pi_2 \\
V_2 &= (1-s)\pi_2 + s\pi_1 \propto \pi_2 + \lambda\pi_1
\end{aligned}
$$

where $\lambda = s/(1-s)$ is the "degree of sympathy" to the rival firm.

Lemma 3. *Partial cross-ownership increases the welfare improving effects of green collusion if* $d < \frac{3+2\gamma}{4}$.

Proof See the appendix.

5.2 Product Differentiation with WTP for Sustainable Products

In this model there is no regulatory agency, but consumers value green/sustainable products more, they are willing to pay a green premium gz_1 which is proportional to the marginal sustainability cost γ. Inverse demand functions for product varieties 1 and 2 are

$$
\begin{aligned}
p_1 &= a + gz_1 - q_1 - \delta q_2, \\
p_2 &= a + gz_2 - q_2 - \delta q_1.
\end{aligned}
$$

Profits are

$$
\pi_i(q_1, q_2, z_1, z_2) = pq_i - cq_i - \frac{1}{2}\gamma(z_i)^2
$$

A two stage game where firms choose the sustainability levels of their products either independently (competition) or jointly (collusion) and in the second stage they choose output competing Cournot style. We obtain the following result.

Lemma 4. *When consumers value sustainanble products more, coordination in sustainability can be welfare improving, lead to more green investment, more profit and higher consumer surplus, if*

$$\frac{2g^2}{(2+\delta)^2} < \gamma < \frac{g^2(\delta-4)}{(\delta-2)(2+\delta)^2}$$

The above lemma is true when for instance $g > \gamma > 3$.

6 Conclusions

Our results provide theoretical support on the desirability of sustainable agreements.

We provide a simple rule for approving green collusion that relies on two variables that may be observed or estimated, in particular the degree of environmental damage and the marginal abatement cost. When the environmental damage of production is relatively lower compared to the abatement cost, green collusion should be allowed.

The robustness of this result should be checked under various model specifications.

A Appendix (incomplete)

Proof of Lemma 1: Equilibrium values at Cournot-Cournot (CC) are:

$z_1^{CC} = z_2^{CC} = \frac{(a-c)\left(-1+4d+8d^2\right)}{2(\gamma+d(9+14d+4(1+d)\gamma))}, q_1^{CC} = q_2^{CC} = \frac{(a-c)(\gamma+d(7+8d+2\gamma))}{2(\gamma+d(9+14d+4(1+d)\gamma))}, t^{CC} = \frac{(a-c)(-\gamma+d(-3+2\gamma+d(4+8\gamma)))}{2(\gamma+d(9+14d+4(1+d)\gamma))},$

$\Pi_1^{CC} = \Pi_2^{CC} = \frac{(a-c)^2\left(2d(1+3d)(3+8d(3+4d))+\gamma+8d(3+d(9+4d(3+2d)))\gamma+2(\gamma+2d\gamma)^2\right)}{8(\gamma+d(9+14d+4(1+d)\gamma))^2},$

$W^{CC} = \frac{(a-c)^2\left(2d(5d(1+2d)(13+16d)-2)+(4d(1+2d)(3+2d)(3+4d))\gamma+2(1+2d)^3\gamma^2-1\right)}{4(\gamma+d(9+14d+4(1+d)\gamma))^2}, ED^{CC} = \frac{(a-c)^2 d(1+\gamma+d(3+2\gamma))^2}{(\gamma+d(9+14d+4(1+d)\gamma))^2}$

$PS^{CC} = \frac{(a-c)^2\left(2d(1+3d)(3+8d(3+4d))+\gamma+8d(3+d(9+4d(3+2d)))\gamma+2(\gamma+2d\gamma)^2\right)}{4(\gamma+d(9+14d+4(1+d)\gamma))^2},$

$CS^{CC} = \frac{(a-c)^2(\gamma+d(7+8d+2\gamma))^2}{2(\gamma+d(9+14d+4(1+d)\gamma))^2}, EM^{CC} = \frac{(a-c)(1+\gamma+d(3+2\gamma))}{\gamma+d(9+14d+4(1+d)\gamma)},$

$T^{CC} = \frac{(a-c)^2(1+\gamma+d(3+2\gamma))(-\gamma+d(-3+2\gamma+d(4+8\gamma)))}{2(\gamma+d(9+14d+4(1+d)\gamma))^2}, p^{CC} = a - \frac{(a-c)(\gamma+d(7+8d+2\gamma))}{\gamma+d(9+14d+4(1+d)\gamma)}.$

For the Cartel-Cournot (KC) case, equilibrium values are:

$z_1^{KC} = z_2^{KC} = \frac{(a-c)\left(-1+6d+8d^2\right)}{2\gamma+8d(3+\gamma+d(4+\gamma))}, q_1^{KC} = q_2^{KC} = \frac{(a-c)(\gamma+2d(5+4d+\gamma))}{2\gamma+8d(3+\gamma+d(4+\gamma))}, t^{KC} = \frac{(a-c)(-\gamma+2d(-3+\gamma+4d(1+\gamma)))}{2\gamma+8d(3+\gamma+d(4+\gamma))},$

$\Pi_1^{KC} = \Pi_2^{KC} = \frac{(a-c)^2\left((1+4d)^2+2\gamma\right)}{8(\gamma+4d(3+\gamma+d(4+\gamma)))},$

$W = \frac{(a-c)^2\left(4d(-1+2d(31+16d(5+3d)))+(-1+4d(13+d(43+16d(3+d))))\gamma+2(1+2d)^3\gamma^2\right)}{4(\gamma+4d(3+\gamma+d(4+\gamma)))^2},$

$ED^{KC} = \frac{d(a-c)^2(\gamma+2(\gamma+2)d+1)^2}{(\gamma+4d(\gamma+(\gamma+4)d+3))^2}, PS^{KC} = \frac{(a-c)^2\left((1+4d)^2+2\gamma\right)}{4(\gamma+4d(3+\gamma+d(4+\gamma)))}, CS = \frac{(a-c)^2(\gamma+2d(5+4d+\gamma))^2}{2(\gamma+4d(3+\gamma+d(4+\gamma)))^2}$
$EM^{KC} = \frac{(a-c)(1+\gamma+2d(2+\gamma))}{\gamma+4d(3+\gamma+d(4+\gamma))}, T^{KC} = \frac{(a-c)^2(1+\gamma+2d(2+\gamma))(-\gamma+2d(-3+\gamma+4d(1+\gamma)))}{2(\gamma+4d(3+\gamma+d(4+\gamma)))^2},$
$p^{KC} = a - \frac{2(a-c)(\gamma+2d(5+4d+\gamma))}{2\gamma+8d(3+\gamma+d(4+\gamma))}.$

Concerning total welfare:

$$W^{CC} - W^{KC} = \frac{A}{B}$$

where

$A = d(2d+1)^2(a-c)^2(-2\gamma+4d-3)[2\gamma^2+16(7\gamma+26)d^4+(4\gamma(29-2\gamma)+408)d^3+12(6\gamma+7)d^2+\gamma(6\gamma+29)d]$ and $B = 4(\gamma+d(4\gamma(d+1)+14d+9))^2(\gamma+4d(\gamma+(\gamma+4)d+3))^2$. $B > 0$ and $A < 0$ for $0 < \gamma < 64,21$ and $d < \frac{3+2\gamma}{4}$. Also for $d < \frac{3+2\gamma}{4}$ total investment in green technology:

$$\left(z_1^{CC}+z_2^{CC}\right)-\left(z_1^{KC}+z_2^{KC}\right) = \frac{d(2d+1)^2(a-c)(-2\gamma+4d-3)}{(\gamma+d(4\gamma(d+1)+14d+9))(\gamma+4d(\gamma+(\gamma+4)d+3))} < 0$$

and concerning environmental damage, individual profits, quantities and consumer surplus:

$$ED^{CC}-ED^{KC} = d(a-c)^2\left(\frac{(\gamma+(2\gamma+3)d+1)^2}{(\gamma+d(4\gamma(d+1)+14d+9))^2} - \frac{(\gamma+2(\gamma+2)d+1)^2}{(\gamma+4d(\gamma+(\gamma+4)d+3))^2}\right) > 0$$

$$\pi_i^{CC} - \pi_i^{KC} = \frac{d^2(2d+1)^2(a-c)^2(2\gamma-4d+3)^2}{8(\gamma+d(4\gamma(d+1)+14d+9))^2(\gamma+4d(\gamma+(\gamma+4)d+3))} < 0$$

$$\left(q_1^{CC}+q_2^{CC}\right)-\left(q_1^{KC}+q_2^{KC}\right) = \frac{2d^2(2d+1)(a-c)(-2\gamma+4d-3)}{(\gamma+d(4\gamma(d+1)+14d+9))(\gamma+4d(\gamma+(\gamma+4)d+3))} < 0$$

$$CS^{CC}-CS^{KC} = \frac{1}{2}(a-c)^2\left(\frac{(\gamma+d(2\gamma+8d+7))^2}{(\gamma+d(4\gamma(d+1)+14d+9))^2} - \frac{(\gamma+2d(\gamma+4d+5))^2}{(\gamma+4d(\gamma+(\gamma+4)d+3))^2}\right) < 0$$

Proof of Lemma 2: Omitted.

Proof of Lemma 3: Omitted.

Proof of Lemma 4: Omitted.

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