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Abstract

In a recent paper, Creane and Miyagiwa (2008) show that the mode of competition (quantity or price) determines whether information sharing occurs between firms and governments within an international duopoly context in which the fims are located in different countries. In this paper, we show that the relative number of firms located in each country is also critical. In particular, we illustrate that with quantity competition and under the presence of demand and cost uncertainty information sharing does not occur when the number of firms in one country is higher than the number of firms in the other country. Moreover, we show that the informational prisoner's dilemma in the current context appears only when the number of firms across countries is equal.

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1 Introduction

In a recent paper, Creane and Miyagiwa (2008), hereafter CM, show that the standard assumption in the Brander-Spencer setting (see Brander and Spencer 1985), which states that governments have complete information about the economy, is justified when firms compete over quantities. However, the assumption of informed governments does not hold under Bertrand competition. This is because firms have an incentive to disclose their private information regarding the exact demand and cost levels under Cournot competition, while they do not under price competition. Thus, the governments remain uninformed in equilibrium. This result is founded on the fact that when the firms reveal information to the government, they adjust their subsidies accordingly. This increases the variability of outputs and leads towards higher expected profits and welfare levels.

The analysis of CM assumes that two firms from two different countries compete in a third country market. When CM discuss possible extensions of their model in the summary section, they claim that the introduction of multiple firms is expected to keep the results intact. "Consider, for example, what would occur if each country has multiple firms.... If firms compete in quantities, then government intervention will still increase the convexity of the profit function of each firm, thereby inducing government learning in equilibrium," Creane and Miyagiwa (2008), p. 239.[1]

Within a framework that is essentially that of CM but appropriately modified to deal with multiple firms in each country, this paper shows that when firms compete over quantities, the relative number of firms in each country is a critical determinant of information sharing between the firms and the governments. In particular, when two countries are asymmetric in terms of the number of firms located in each of them, information disclosure will occur only in the country that subsidizes production, i.e., the country with relatively few firms. In the rival country, the firms will prefer to keep information private because the government implements an export tax. When there are several firms, CM's model applies to both information sharing and the informational prisoner's dilemma in the special case of an equal number of firms in each country. This argument aims to provide an explanation as to why some countries' firms and governments share information and why others do not.

[1] Emphasis in original.

2 The Model

2.1 Basic Assumptions

The bones of our model are those of CM; the departure is the consideration of multiple firms in each country. The model features two countries, Country 1 and Country 2, that export a homogeneous good to a third market.The number of firms in Countries 1 and 2 is exogenously given by n and m , respectively.[2] Total production by the $n+m$ firms is exported to the rest of the world. The linear inverse demand function of the homogeneous good is $p = A - \sum_{i=1}^{n} q_i - \sum_{j=1}^{m} Q_j + \theta$ where θ represents a shock in demand, which follows a distribution with zero mean and variance equal to $var(\theta)$. We further assume that the firms in Country 1 produce its goods with common constant marginal costs of $(c_i + u_i)$ for firms in Country 1 and $(c_j + u_j)$ for firms in country 2. The terms u_i (common for the firms in Country 1) and u_j (common for the firms in Country 2) are stochastic terms revealed to the firms. They are independently distributed and follow a distribution with zero mean and, for simplicity, variances are equal to $var(u_i) = var(u_j) = var(u)$ as in the original CM model. Country 1's government sets a subsidy (or a tax) $s_i > 0$ ($s_i < 0$) to maximize the domestic welfare $w = \sum_{i=1}^{n} \pi_i - (\sum_{i=1}^{n} s_i q_i)$, where $\pi_i = p(\cdot) q_i + s_i q_i$ denote the profits of a typical firm residing in that country. A similar game is played in Country 2.

2.2 Staging of the Game

In *Stage 1* of the game, the firms and governments simultaneously decide whether they will establish an agreement about sharing information or not. If they do, then we assume that no participant will break up the agreement because they will incur high costs for doing so. In *Stage 2*, nature defines the new values for the demand and/or the cost parameters and reveals them to the firms. If the participants agreed in the first stage to share information, then the firms reveal the updated statuses of demand and costs to the governments. In *Stage 3*, the two governments select an optimal policy of promoting or demoting exports through an export subsidy or export tax, respectively. Finally, in *Stage 4*, the firms compete à la Cournot.

In order to determine the final outcome, we need to compute the expected values of profits

[2] Throughout the paper the Country 1 variables will be denoted by lower case letters and Country 2 variables will be denoted by upper case letters.

and welfare for each possible contingency and then compare the individual outcomes. Because the model evolves in four stages, we will solve it backwards.

2.3 Complete information

Here we assume that the governments and the firms agree in Stage 1 to share information. In Stage 4 the firms compete à la Cournot and thus outputs are the following:[3]

$$\begin{aligned} q_i &= \frac{[(A+\theta)-(1+m)(c_i-s_i+u_i)+m(c_j-S_j+u_j)]}{(1+n+m)} \\ \text{and } Q_j &= \frac{[(A+\theta)-(1+n)(c_j-S_j+u_j)+n(c_i-s_i+u_i)]}{(1+n+m)}. \end{aligned} \tag{1}$$

The two governments determine the optimal policy by maximizing their national welfare, given the fourth stage outputs from the equation (1). Therefore, we obtain:

$$\begin{aligned} s_i^{cc} &= \underbrace{-\frac{(n-1-m)[A+c_j(1+n)-c_i(2+n)]}{n(3+n+m)}}_{s_i^{BS}} - \frac{(n-1-m)\theta}{n(3+n+m)} + \frac{(n-1-m)u_i}{2n}, \\ \text{and } S_j^{cc} &= \underbrace{-\frac{(m-1-n)[A+c_i(1+m)-c_j(2+m)]}{m(3+n+m)}}_{S_j^{BS}} - \frac{(m-1-n)\theta}{m(3+n+m)} + \frac{(m-1-n)u_j}{2m}. \end{aligned} \tag{2}$$

The superscript cc over subsidy levels denotes that there is complete information in both countries, while BS denotes the Brander-Spencer outcomes when $var(u) = var(\theta) = 0$. Assuming that the demand intercept is sufficiently high to imply the existence of an interior solution, from (2), we observe that whether a government will set a subsidy or a tax depends on the number of firms in the two countries. For instance, the government in Country 1 will set a subsidy (tax) if and only if $n < m+1$ ($n > m+1$). This means that a subsidy is imposed if the number of firms in a country is less than or equal to the number of firms residing in the rival country. Hence, if the number of firms is equal across countries then a subsidy is implemented by both governments. The fact that the governments are informed by the firms is reflected by the policy levels, which adjust accordingly for the shocks θ, u_i and u_j.

Substituting the values given in (2) into (1) we obtain the Subgame Perfect Nash Equilibrium

[3] Because the firms in each country are symmetric, we anticipate that in equilibrium the level of the subsidy (tax) will be the same for all the firms residing in the same country, in order to keep the analysis clear.

of this game. Next, we replace the equilibrium values into Country's 1 and 2 profit and welfare functions and taking expectations we get:

$$\begin{aligned}
E[\pi_i^{cc}] &= \pi_i^{BS} + \frac{n^2+(1+m)^2}{4n^2}var(u) + \frac{(1+m)^2}{n^2(3+n+m)^2}var(\theta), \\
E[\Pi_j^{cc}] &= \Pi_j^{BS} + \frac{m^2+(1+n)^2}{4m^2}var(u) + \frac{(1+n)^2}{m^2(3+n+m)^2}var(\theta), \\
E[w_i^{cc}] &= w_i^{BS} + \frac{(1+n+m)}{4n}var(u) + \frac{(1+m)}{n(3+n+m)^2}var(\theta) \\
\text{and } E[W_j^{cc}] &= w_j^{BS} + \frac{(1+n+m)}{4m}var(u) + \frac{(1+n)}{m(3+n+m)^2}var(\theta).
\end{aligned} \tag{3}$$

From (3) we observe that the expected profits and welfare levels in both countries depend positively on $var(u)$ and $var(\theta)$. This is attributed to the convexity of the profit function with respect to the demand intercept and the marginal cost of production.

2.4 Incomplete information

When the firms and the governments do not reach an agreement about information sharing in the first stage, then the governments act under incomplete information. Equilibrium outputs in the fourth stage are given again by (1). What changes is the behavior of the governments in Stage 3 where they maximize the expected welfare levels. Hence, the equilibrium policy levels follow:

$$\begin{aligned}
s_i^{nn} &= s_i^{BS} \\
\text{and } S_j^{nn} &= S_i^{BS}.
\end{aligned} \tag{4}$$

From (4) we observe that the subsidies in the case of the governments remaining uninformed (denoted by nn) equal the ones of the original Brander-Spencer setting with no uncertainty (see (2)). Substituting the values given in (4) into (1) we obtain the Bayes Nash Equilibrium of this game. Subsequently, we replace the equilibrium values into Country's 1 and 2 profit and welfare functions and taking expectations we get:

$$\begin{aligned} E[\pi_i^{nn}] &= \pi_i^{BS} + \frac{1+2m(1+m)}{(1+n+m)^2} var(u) + \frac{1}{(1+n+m)^2} var(\theta), \\ E[\Pi_j^{nn}] &= \Pi_j^{BS} + \frac{1+2n(1+n)}{(1+n+m)^2} var(u) + \frac{1}{(1+n+m)^2} var(\theta), \\ E[w_i^{nn}] &= w_i^{BS} + \frac{1+2m(1+m)}{(1+n+m)^2} var(u) + \frac{1}{(1+n+m)^2} var(\theta) \\ \text{and } E[W_j^{nn}] &= w_j^{BS} + \frac{1+2n(1+n)}{(1+n+m)^2} var(u) + \frac{1}{(1+n+m)^2} var(\theta). \end{aligned} \tag{5}$$

Again, all of the expected values depend positively on $var(u)$ and $var(\theta)$ due to the convexity of the profit function with respect to θ, c_i and c_j.

The last scenario that must be examined before completing the full payoff matrix is the asymmetric case in which a pair, i.e., one government and a typical firm, agrees to share information while the rival one, i.e., the other government and a typical firm, does not. The calculations are trivial and thus for brevity they are relegated to the Appendix.

3 Results

3.1 Information Sharing Game

So far we have determined the expected values of profits and welfare levels for the participants in the two countries for every possible contingency. Therefore, the full payoff matrices that the participants face in the first stage are now complete. The following Lemmas provide the optimal responses for every possible subcase both for a firm and the government residing in Country 1:

Lemma 1 *With unknown marginal cost of production: (a) For the government, it is a strictly dominant strategy to obtain information regardless of the number of firms in the two countries. (b) For the firm, (i) if* $n < m+1$*, it is a strictly dominant strategy to share information, (ii) if* $n = m+1$*, the firm is indifferent, and (iii) if* $n > m+1$*, it is a strictly dominant strategy not to reveal information.*

Proof in Appendix■

Lemma 2 *With unknown demand intercept: (a) For the government, (i) if the rival pair does not share information then the government always prefers to obtain information. (ii) If the rival* *pair shares information, then obtaining information is a strictly dominant strategy if* $\frac{4+4n+n^2}{n} > m+1 > n$. *If* $\frac{4+4n+n^2}{n} = m+1$ *or* $m+1 = n$ *then the government is indifferent, and if* $m+1 > \frac{4+4n+n^2}{n}$ *or* $m+1 < n$ *then obtaining information yields lower expected welfare than remaining uninformed. (b) For the firm, Lemma 1 is replicated.*

Proof in Appendix■

Given the optimal responses for every possible contingency we can now determine the equilibria of the game in the following Proposition:

Proposition 1 *(i) The firm and the government in Country 1 share information when* $n < m+1$, *while in Country 2 they share information when* $m < n+1$. *(ii) If* $n = m+1$, *then in Country 1 the firms and government are indifferent, while in Country 2 the firms and government agree to share information. (iii) The firms and government in Country 1 do not share information when* $n > m+1$, *while in Country 2 they do not share information when* $m > n+1$.[4]

Proposition 1 summarizes the possible outcomes that may occur given the number of firms located in each of the two countries. If the number of firms residing in Country 1 is less than or equal to the number of firms in the rival country, then the firms and the government in Country 1 are expected to reach an agreement. If this is the case, then what happens in Country 2 regarding information sharing depends on whether the number of firms in that country equals the number of firms in Country 1. If the number of firms in both countries is the same, then information sharing occurs in Country 2 as well. Our results generalize CM 's basic result which suggests that when a single firm is active in each country competing in quantities with the rival firm under both demand and marginal cost uncertainty, then information sharing occurs in equilibrium in both countries. It follows from Proposition 1 that this is true even if we allow for many firms residing in each country as long as the number of firms is equal across the two countries. Introducing an asymmetry in the number of firms across the two countries fundamentally alters the results.

The driving forces behind this are straightforward. From (2) we observe that the government in Country 1 subsidizes the exporting firms when $n < m+1$. If $n = m+1$, then the optimal policy is a zero subsidy. If $n > m+1$, then the government implements an export tax. Assuming in the

[4] The proof of Proposition 1 directly follows from Lemmas 1 and 2. Note also that the inequality conditions given here denote the necessary conditions. The sufficient condition for Country 1 in order to have information sharing is $\frac{4+4n+n^2}{n} > m+1 > n$.

first scenario that a firm reveals information then the government in Country 1 adjusts its policy according to the values of θ and u_i. In particular, it follows from (2) that in good times (positive θ or negative u_i) the subsidy increases, while in bad times it decreases. This, in turn, increases convexity of the profit function leading to higher expected profits and welfare levels. However, if $n > m + 1$, then good news forces the government to increase the tax, which translates into bad news for the firm. In contrast, bad news leads to a reduction of the tax. Due to this governmental behavior, flexibility is reduced. Thus, expected profits and welfare levels are now lower. In this case, the firms prefer to keep their government uninformed. This result contrasts with CM's result that ignores the different number of firms across countries.

3.2 Informational Prisoner's Dilemma

In their study CM establish the existence of an informational prisoners dilemma with demand uncertainty and quantity competition. This means that although in equilibrium the firms and the government in each country share information this is sub-optimal from the national welfare perspective. On the contrary, when a government is uncertain only with respect to the marginal cost of production, then the informational prisoner's dilemma disappears. In a multiple firms setting, an informational prisoner's dilemma may occur only when, in equilibrium, the firms and the governments agree to share information in both countries simultaneously. Given the analysis thus far, this holds only for the case where the number of the firms in the two countries is equal, i.e., $n = m$. The following Proposition summarizes these arguments for the multiple firms case:

Proposition 2 *If $n = m$, then (a) with demand uncertainty, an informational prisoner's dilemma occurs and (b) with cost uncertainty, no informational prisoner's dilemma exists.*

Proof in Appendix■

Not surprisingly, CM's implications about the informational prisoner's dilemma are also obtained in the current multiple firms framework, as long as we allow for the same number of firms across the two countries. In the case of demand uncertainty, each government would prefer the rival pair not to share information, irrespective of what happens in that country regarding an agreement over information sharing. When the pair in Country 2 shares information about the exact value of

θ, then the convexity of the profit function with respect to θ in Country 1 decreases and the reverse also occurs. Hence, information sharing in the two countries is undesirable.

The key feature in the case of demand uncertainty that leads to the informational prisoner's dilemma is that θ is common in both countries. If, however, there is uncertainty over the firms' costs, then an informational prisoner's dilemma is not present in equilibrium as suggested in part (b) of Proposition 2. That is because the shocks in the two countries are not correlated. Now, if the firms and the government in Country 2 agree over information sharing then any changes in u_j increase the volatility of their outputs with respect to that shock. As a result, the convexity of the profit function for a typical firm in Country 1 with respect to u_j, and thus expected welfare in that country, increases with $var(u)$.

For the more important cases of an asymmetric number of firms in the two countries, an informational prisoner's dilemma as defined by CM cannot occur because information sharing in both countries does not occur in equilibrium. The reader might wonder whether this warrants examining a modified scenario in which the residents of the two countries are not satisfied with the obtained equilibrium. It is clear that this cannot be the case. Even in the imaginary scenario where expected welfare in a country would be higher if the rival pair would decide differently compared to what it does in equilibrium, it can be shown that this would violate the optimal behavior of the government in the rival country. Stated it differently, expected welfare would be lower in the other country. Thus, a modified version of the prisoner's dilemma where the residents in both countries are better off away from the equilibrium is not feasible.

4 Discussion-Implications

A recent contribution by CM has shown that under Cournot Competition, firms have an incentive to reveal demand and cost information to the governments, while under Bertrand competition governments remain uninformed. Moreover, CM establish the informational prisoner's dilemma under quantity competition and unknown demand. A crucial element of their analysis is that there is only one firm located in each country.While this assumption is a good starting point to understand the issues, it is not the most realistic one.

This paper has introduced multiple firms in the framework of CM and has shown that when firms compete over quantities, the number of firms in the country is a critical determinant of information sharing between firms and governments. Information sharing occurs in the case of multiple firms, if the number of firms in a country is less than or equal to the number of firms in the rival country. This means that information sharing occurs as long as a government implements an export subsidy. Moreover, it is shown that for the special case where the number of firms is equal in the two countries, the informational prisoner's dilemma still arises under demand uncertainty, while it does not under cost uncertainty.

The reader might wonder about extending this study to cover cases in which firms compete in prices. This question is irrelevant because the addition of extra firms in the model will not add anything. This is due to an export tax being the optimal policy for a government regardless of the number of firms in the two countries (see Eaton and Grossman 1986; Section *IV*).

This study is in line with CM and highlights instances where examining private information models in strategic trade policy might be an irrelevant issue because it is resolved endogenously under the conditions described here. This has the potential to open a new direction in the policy instrument choice literature. For example, Cooper and Riezman (1989) illustrated that subsidies might be preferred over quotas due to higher flexibility under uncertainty. Yet, if the problem of uncertainty is resolved, it is more than possible that quotas might gain back their advantage as a policy instrument over subsidies.

Appendix

Calculations of Subsidies and Expected Values for the Asymmetric Case:

Given Stage 4 equilibrium outputs (1) the policy levels are the following:

$$\begin{aligned} s_i^{cn} &= s_i^{BS} - \frac{(n-1-m)\theta}{2n(1+m)} + \frac{(n-1-m)u_i}{2n} \text{ and } S_j^{cn} = S_i^{BS} \\ s_i^{nc} &= s_i^{BS} \text{ and } S_j^{cn} = S_i^{BS} - \frac{(m-1-n)\theta}{2m(1+n)} + \frac{(m-1-n)u_j}{2m} \end{aligned}$$

Here, the superscripts *cn* describe the situation in which the pair in Country 1 reach an agreement about information sharing and the pair in Country 2 does not, and *nc* the reverse.

The expected values of profits and welfare levels for Country 1 are now:

$$
\begin{aligned}
E[\pi_i^{cn}] &= \pi_i^{BS} + \frac{2n(1+m)^3 + (1+m)^4 + n^2[1+m(2+5m)]}{4n^2(1+n+m)^2} var(u) + \frac{1}{4n^2} var(\theta), \\
E[\pi_i^{nc}] &= \pi_i^{BS} + \frac{5(1+m)^2 + 2(1+m)n + n^2}{4(1+n+m)^2} var(u) + \frac{1}{4(1+n)^2} var(\theta), \\
E[w_i^{cn}] &= w_i^{BS} + \frac{n^2(1+m) + (1+m)^3 + n(2+4m+6m^2)}{4n(1+n+m)^2} var(u) + \frac{1}{4n(1+m)} var(\theta) \\
\text{and } E[w_i^{nc}] &= w_i^{BS} + \frac{5(1+m)^2 + 2(1+m)n + n^2}{4(1+n+m)^2} var(u) + \frac{1}{4(1+n)^2} var(\theta). \qquad \text{(A1)}
\end{aligned}
$$

Proof of Lemma 1:

(a) It is sufficient to show through the use of the relevant equations from (3), (5) and (A1) that $E[w_i^{cn}] - E[w_i^{nn}] > 0$ and $E[w_i^{cc}] - E[w_i^{nc}] > 0$. Therefore, we get:

$$
\begin{aligned}
E[w_i^{cn}] - E[w_i^{nn}] &= \frac{(1-n+m)^2(1+m)}{4n(1+n+m)^2} var(u) > 0 \\
\text{and } E[w_i^{cc}] - E[w_i^{nc}] &= \frac{(1-n+m)^2(1+m)}{4n(1+n+m)^2} var(u) > 0.
\end{aligned}
$$

Q.E.D.

(b) Similarly we compare $E[\pi_i^{cn}] - E[\pi_i^{nn}]$ and $E[\pi_i^{cc}] - E[\pi_i^{nc}]$. We obtain:

$$
\begin{aligned}
E[\pi_i^{cn}] - E[\pi_i^{nn}] &= \frac{(m+1-n)(1+3n+m)(1+m)^2}{4n^2(1+n+m)^2} var(u) \\
\text{and } E[\pi_i^{cc}] - E[\pi_i^{nc}] &= \frac{(m+1-n)(1+m)^2(1+m+3n)}{4n^2(1+n+m)^2} var(u).
\end{aligned}
$$

(i) If $n < 1+m \Rightarrow E[\pi_i^{cn}] - E[\pi_i^{nn}] > 0$ and $E[\pi_i^{cc}] - E[\pi_i^{nc}] > 0$, (ii) If $n = 1+m \Rightarrow E[\pi_i^{cn}] - E[\pi_i^{nn}] = 0$ and $E[\pi_i^{cc}] - E[\pi_i^{nc}] = 0$ and (iii) If $n > 1+m \Rightarrow E[\pi_i^{cn}] - E[\pi_i^{nn}] > 0$ and $E[\pi_i^{cc}] - E[\pi_i^{nc}] < 0$. Q.E.D.

Proof of Lemma 2:

(a) Doing similar calculations with those of the previous Lemma, we get:

(i)

$$E[w_i^{cn}] - E[w_i^{nn}] = \frac{(1-n+m)^2}{4n(1+m)(1+n+m)^2} var(\theta) > 0.$$

(ii)

$$E[w_i^{cc}] - E[w_i^{nc}] = -\frac{(n-1-m)[4+n(3-m+n)]}{4n(1+n)^2(3+n+m)^2}var(\theta).$$

If $n < m+1$ and $4+n(3-m+n) > 0 \Leftrightarrow \frac{4+3n+n^2}{n} > m \Leftrightarrow \frac{4+3n+n^2}{n} + 1 > m+1 \Leftrightarrow \frac{4+4n+n^2}{n} > m+1$ $\Rightarrow E[w_i^{cc}] - E[w_i^{nc}] > 0$. If $n = m+1$ or $\frac{4+4n+n^2}{n} = m+1 \Rightarrow E[w_i^{cc}] - E[w_i^{nc}] = 0$. Finally, if $m+1 > \frac{4+4n+n^2}{n}$ or $n > m+1 \Rightarrow E[w_i^{cc}] - E[w_i^{nc}] < 0$. Q.E.D.

(b) We compare $E[\pi_i^{cn}] - E[\pi_i^{nn}]$ and $E[\pi_i^{cc}] - E[\pi_i^{nc}]$:

$$\begin{aligned} E[\pi_i^{cn}] - E[\pi_i^{nn}] &= \frac{(m+1-n)(1+3n+m)}{4n^2(1+n+m)^2}var(\theta) \\ \text{and } E[\pi_i^{cc}] - E[\pi_i^{nc}] &= \frac{(m+1-n)(2+n)[2(1+m)+n(5+n+3m)]}{4(3+n+m)^2(n+n^2)^2}var(\theta). \end{aligned}$$

(i) If $n < 1+m \Rightarrow E[\pi_i^{cn}] - E[\pi_i^{nn}] > 0$ and $E[\pi_i^{cc}] - E[\pi_i^{nc}] > 0$, (ii) If $n = 1+m \Rightarrow E[\pi_i^{cn}] - E[\pi_i^{nn}] = 0$ and $E[\pi_i^{cc}] - E[\pi_i^{nc}] = 0$ and (iii) If $n > 1+m \Rightarrow E[\pi_i^{cn}] - E[\pi_i^{nn}] < 0$ and $E[\pi_i^{cc}] - E[\pi_i^{nc}] < 0$ Q.E.D.

Proof of Proposition 2:

(a) We set $var(u) = 0$. Then:

$$E[w_i^{cc}] - E[w_i^{nn}] = \frac{[1-4n(1+n)]}{n(3+4n(2+n))^2}var(\theta) < 0 \text{ as } n \geq 1.$$

Alternatively, it can be shown as in CM that $E[w_i^{cc}] - E[w_i^{cn}] < 0$ and $E[w_i^{nn}] - E[w_i^{nc}] > 0$ Q.E.D.

(b) We set $var(\theta) = 0$. Then:

$$E[w_i^{cc}] - E[w_i^{nn}] = \frac{(1+2n+4n^2)}{4n(1+2n)^2}var(u) > 0 \text{ as } n \geq 1.$$

Alternatively it can be shown as in CM that $E[w_i^{cc}] - E[w_i^{cn}] > 0$ and $E[w_i^{nn}] - E[w_i^{nc}] < 0$ Q.E.D.

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