Economics Bulletin

Volume 36, Issue 3

On the price effects of collusion and the number of firms.

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Abstract

This note considers a theoretical model where firms are able to coordinate on distinct output levels than the monopoly outcome. In our model, the degree of collusion (captured by the coefficient of cooperation) and the number of firms are only imperfect substitutes in order to maximize consumer surplus. The main implication of this finding is that policy measures devoted to increase the number of competitors are more effective when the degree of collusion is small whereas the efforts to discourage collusion should be applied especially in markets with many firms. The results are also robust to other ways to parameterize the product-market competition.

Financial support by the "Ministerio de Economía y Competitividad" and the "Fondo Europeo de Desarrollo Regional" through the project "Conflicto e influencia estratégica: Los efectos de la actividades de captación de rentas en las decisiones colectivas" (Ref: ECO2015-67901-P MINECO/FEDER) is gratefully acknowledged. The usual disclaimer applies.
Citation: Marc Escrihuela-Villar, (2016) "On the price effects of collusion and the number of firms.", *Economics Bulletin*, Volume 36, Issue 3, pages 1694-1704
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Submitted: May 12, 2016. **Published:** September 03, 2016.

1 Introduction

The analysis of the degree of competition in a market is of major concern for economists and policy makers. Non-competitive behavior includes, but is not limited to, collusive agreements and the market structure given for instance by a small number of firms in an industry. A common problem for antitrust authorities is thus the trade-off in welfare terms between the number of competitors and the degree of competition. An example is provided in Brander and Spencer (1985) where it is stated that a large class of industries (like providers of professional services) seem to be characterized by partial collusion and free entry. Obviously, policies which render tacit collusion more difficult are in the public interest. They argue, however, that a license fee simply taxing entrants might be welfare improving. The number of firms falls and consequently collusion is made easier but the output per firm may raise lowering average costs.[1] This is also reflected in the fact that regulators with limited resources must often decide whether to allocate them to measures that facilitate entry or to measures designed to promote more competitive behavior by existing firms. Unfortunately, the standard one-shot quantity-setting and homogeneous product model does not provide a strong answer in this respect since price is a decreasing function of the number of firms, but the concept of "degree of collusion" is not considered as a determinant of the welfare consequences of the number of firms.[2] The Industrial Organization analysis of tacit collusion in quantity-setting supergames has often considered the possibility of a collusive agreement to implement the joint monopoly outcome. Then, the potential sustainability of the collusive agreements is reflected in the minimum discount factor above which the monopoly outcome could be sustained and reducing the number of competitors facilitates collusion. This exercise, however, does not allow us to consider the aforementioned trade-off since only full collusion might exist if the discount factor is large enough. Some other papers have considered the degree of competitiveness of the market in terms of the slope of the supply curves (see for example Vives (2011)). This literature, however, does not analyze the welfare effects of the trade-off mentioned above. On the other hand, in a paper with which our work is most closely related to,

[1] Another example could be the measures designed to promote more competitive behavior in a market that may lead to the exit of firms. In this line, Dewey (1979) asserts that collusion has been observed in low profit industries as barber shops or hot dog stands in midtown Manhattan. This sort of collusion might increase welfare by inducing entry of new firms and cannot be aimed at increasing monopoly rents because, eventually, free entry keeps monopoly profits equal to zero.

[2] In this setting Salant, Switzer and Reynolds (1983) show that collusive agreements are (generally) not profitable because non participating firms react to collusion by expanding their production.

Menezes and Quiggin (2012) use the perceived slope of competitors' supply functions as the intensity of competition to show that total welfare increases monotonically with the intensity of competition and the number of competitors. Menezes and Quiggin, however, do not consider a collusive market where firms might maximize joint profits. In contrast, we consider a model where firms maximize joint profits but where coordination on distinct output levels than the monopoly outcome may also arise.

Following a recent trend in the literature, we model the intensity of collusion assuming that firms care about their profits plus a weighted average of the profits of the other firms.[3] Using a payoff function based on the relative performance approach (that is evolutionary stable, see Vega-Redondo (1997)) the intensity of competition can be parameterized. Intermediate values of this parameter then, might represent imperfect collusion and may also be justified by reference to some implicit dynamic model of collusion, a reduced-form representation of which being the quantity competition subgame of this model. This formulation is closely related to the "coefficient of cooperation" defined by Cyert and DeGroot (1973). Our model thus allows us to treat the degree of collusion as a continuous variable in such a way that the existence of collusion does not depend on the number of firms involved in the agreement.[4]

Our main result shows that the market price sensitivity (i) with respect to the degree of collusion increases with the number of firms, and (ii) with respect to the number of firms decreases with the degree of collusion which implies that price increases due to horizontal mergers, and consequently most probably also their profitability, depend negatively on pre-merger collusion. Another direct implication is also that the trade-off between the number of competitors and the degree of competition should be taken into account since these two market characteristics are not perfect substitutes in welfare terms. Finally, it is also shown that the market price is less sensitive to changes in the degree of collusion than in the number of firms only when collusion is low enough since in this case, most of the welfare gains from extra competition are captured by an increase in the number of firms. In the appendix we show that the present results also carry over in a model where,

[3] See for instance Symeonidis (2008) for a duopoly or Matsumura et al. (2013) for an oligopoly. Additionally, Escrihuela-Villar (2015) shows that using conjectural variations and the coefficient of cooperation leads to equivalent closed-form solutions.

[4] Even though this might not be accurate, we have particularly in mind situations in which the competitive intensity is exogenous at the firm level since firms' coordination is based, for example, on historical reasons, local legislation or a common corporate culture. Anyway, future research should address this limitation.

as in Verboven (1997) or Escrihuela-Villar (2008a), the degree of collusion is captured by the common discount factor or also in a model of horizontal differentiation with Bertrand competition.

Despite its theoretical viewpoint, our paper is also motivated by real cases. It is well known that one motivation to merge may be associated with the possibility to raise prices.[5] Empirical evidence is copious suggesting that merger incentives are thus related to the pre-merger degree of competition showing that in cartelized industries firms resort to mergers when cartels become a less viable alternative. In this sense, Bittlingmayer (1985) shows that during the Great Merger Wave between 1898 and 1902, mergers in several (cartelized) industries in the U.S. namely cotton oil, sugar, oil, meat packaging or steel and railroading, appear to have been the result of antitrust actions taken against cartels in those industries after the Sherman Act was passed. In the same line, Evenett et al. (2001) examine the samples of international cartels during the 1990s, and observe that mergers are among the different measures adopted by firms for survival in collusive industries where cartel formation is restricted. One can argue thus that a stricter legal enforcement against a cartel increases the relative cost of collusion as compared to merger and consequently firms resort to mergers.

2 The model and results

Consider an industry with $N \geq 2$ firms producing a homogeneous product with production costs normalized to zero. The industry inverse demand is given by the function, $p(Q) = (1-Q)^b$ where Q is the industry output, p is the output price and the parameter $b > 0$ measures the degree of convexity of the inverse demand function. As mentioned in the introduction, we model imperfect collusion assuming that each firm maximizes the sum of its own profit plus the average profits of the remaining firms in such a way that a generic firm i maximizes $\Pi_i + \lambda(\sum_{j\neq i}^{N} \Pi_j)$ where Π_i is the profit of firm $i = 1, 2, ..., N$ and $\lambda \in [0, 1]$, that we assume to be symmetric across firms represents the degree of collusion. The present model encompasses the Cournot case if $\lambda = 0$ and the joint profit maximizing allocation if $\lambda = 1$. This model thus exhibits equilibria where coordination on distinct output levels exists. It can be easily checked that the quantity produced by each firm

[5] Accordingly, the literature on horizontal merger assessment has mainly focused on coordinated effects (if a merger induces rivals to some form of coordination) or unilateral effects (the merged firm charges a higher price) of horizontal mergers.

that we denote by $q(N,\lambda)$,[6] is given by

$$q(N,\lambda) = \left\{ \frac{1}{(b + N + b(N-1)\lambda)} \right. .$$

(Market) price is given by the following expression:

$$p(N,\lambda) = \left\{ \left(\frac{b(1 + (N-1)\lambda)}{b + N + b(N-1)\lambda}\right)^b \right. . \tag{1}$$

To study the welfare effects of the degree of collusion and the number of firms we use total consumer surplus (namely, the market price). In this sense, several recent papers call for antitrust agencies to use a consumer surplus standard rather than a total welfare standard (see for instance Pittman (2007)).[7] We denote the number of firms elasticity of the price by $E_N(N,\lambda) \equiv \frac{\partial p(N,\lambda)}{\partial N}\frac{N}{p(N,\lambda)}$ and the degree of collusion elasticity of the price by $E_\lambda(N,\lambda) \equiv \frac{\partial p(N,\lambda)}{\partial \lambda}\frac{\lambda}{p(N,\lambda)}$. As we prove in the appendix:

Proposition 1 *$\forall N \geq 2$ $E_N(N,\lambda) < 0$ and $E_\lambda(N,\lambda) > 0$. Furthermore, $E_\lambda(N,\lambda)$ increases with N and $|E_N(N,\lambda)|$ decreases with λ.*

Firstly, both $E_N(N,\lambda)$ and $E_\lambda(N,\lambda)$ have the intuitive sign since the price decreases with N and increases with λ. Secondly, (i) the effect on the price of a change in the degree of collusion is greater when there are many firms than when there are few, and (ii) the effect that mergers or the entry of new firms have on the price is higher when the degree of collusion is smaller. Intuitively, when the number of firms is small, the intensity of competition is mostly captured by the number of firms and therefore the price is proportionally less affected by a change in the degree of collusion. Analogously, with a high degree of collusion, most of the gains from extra competition are captured by a decrease in λ and thus with a large λ the price is less sensitive to changes in N.

Corollary 1 *The increase in the price due to an horizontal merger depends negatively on the pre-merger degree of collusion.*

[6] Note that in a collusive equilibrium firms are willing to cut production compared to the Cournot equilibrium ($\frac{\partial q(N,\lambda)}{\partial \lambda} < 0$) and that profits of each firm are enhanced by cartelization ($\frac{\partial \Pi_i}{\partial \lambda} > 0$).

[7] Enforcement practice in most legislations (for instance the horizontal mergers guidelines of the EU) is closer to a consumer welfare standard. The results of the present paper also carry over to the case where total welfare is used instead of consumer surplus. More details are available from the author upon request.

Our results thus corroborate the empirical evidence provided in the introduction suggesting that firms resort to mergers when collusion become a less viable alternative.[8] Corollary 1 thus states that, when the market is (partially) collusive, the effect of mergers on the price is proportionally smaller than in absence of collusion decreasing therefore merger profitability. Horizontal mergers thus would appear most likely in relatively competitive markets, since where firms are already relatively cooperative their private profit gain (derived from a price increase) is no longer likely to be high. Summarizing, we have analyzed the price sensitivity to two different dimensions of non-competitive behavior and we obtained that, *ceteris paribus*, when the market is less competitive in one dimension the price is less sensitive to a change in the other dimension. The comparison of both elasticities confirms that the substitutability between N and λ in order to reduce the price is not perfect and depends crucially on λ.

Proposition 2 $\forall N \geq 2$ $|E_N(N,\lambda)| > E_\lambda(N,\lambda)$ *if* $\lambda < \frac{1}{N}$ *and* $|E_N(N,\lambda)| < E_\lambda(N,\lambda)$ *if* $\lambda > \frac{1}{N}$.

Proposition 2 states that when λ is small enough, the price is more sensitive to changes in N than to changes in λ. The reverse is true when λ is high enough. Both market characteristics considered affect the price and might be substitutes in policy terms since either a large N or a small λ would be sufficient to ensure a competitive market. The present analysis shows, however, that their degree of substitutability is not perfect and depends on the respective value of the market characteristics. Our results also suggest that in order to reduce the price, efforts should be especially focused on regulatory measures designed to increase N when λ is small. In the same line, it seems plausible to recommend that more priority should be given to fight collusion in markets where N is relatively large.[9]

A concrete example may help to highlight the importance of our results: To evaluate competitive concerns, the Antitrust Agencies apply a wide range of analytical tools. For instance, market concentration is often one useful indicator of possible anti-competitive effects of a merger. Then, the lessening of competition resulting from a merger is more likely to be substantial the larger the post-merger market concentration and its change due

[8] Note that this is also coherent with the results in Rodrigues (2001) and Escrihuela-Villar (2008a) showing that merger private profitability is increasing in the expected competitive intensity.

[9] As mentioned in the introduction, it could also be argued that if N increases, it becomes more difficult to sustain collusion. Escrihuela-Villar (2008b) shows, however, that this is not always true when not all the firms participate in the agreement. Note also that we deal here with a model where the existence of collusion depends only on the value of λ regardless of N.

to the merger. More precisely, the Horizontal Merger Guidelines of the U.S. Department of Justice (revised in 2010) state that the mergers resulting in highly concentrated markets (Herfindahl-Hirschman Index, hereafter HHI, above 2500) that involve an increase in the HHI of between 100 and 200 points potentially raise significant competitive concerns and often warrant scrutiny. For example, in our symmetric collusive model if $N = 4$ and two firms merge the HHI changes from 2500 to 3333.3 and this merger would be likely to be challenged. From (1) it is immediate to check that the price increase due to the merger though is quite moderate (smaller than 4% in the linear model of $b = 1$) if $\lambda \geq 0.5$. Conversely, if $N = 8$ and two firms merge, the HHI changes from 1250 to 1428 and therefore, according to the U.S. Guidelines, the merger is unlikely to have adverse competitive effects and requires no further analysis. The price increase due to the merger, however, might be above 12% if $\lambda \simeq 0$.[10]

3 Concluding comments

The present note analyzes the effect of the number of firms and the degree of collusion on the market price as well as how both market characteristics might reinforce each other's effect on the price. The current work adds to the existing literature by examining these questions in an already collusive environment. We show in a fairly general setting that policy interventions regarding the number of firms or the degree of collusion should take into account that both market characteristics lose their degree of substitutability in welfare terms when they reach extreme values. A possible consequence of ignoring these findings is the opportunity cost of implementing ineffective policies. This paper thus highlights that the market structure or the degree of collusion selected by firms can drastically change the potential trade-off between these two market characteristics.

[10] Admittedly, there are also other alternative methodologies for measuring the magnitude of potential unilateral effects of a merger. For instance O'Brien and Salop (2000) or Farrell and Shapiro (2010) have proposed the use of different price pressure indices to aid this analysis. Interestingly enough, the U.S. Merger Guidelines of 2010 state that mergers "should not be permitted to create or enhance market power or to facilitate its exercise." (p. 5). This statement thus appears to represent a policy choice where pre-merger market power is not considered either when price indices are considered in order to assess merger effects. Hence, the only relevant policy concern seems to be to ensure that mergers will not enhance market power.

Appendix

We test whether our results hinge on the assumption made regarding the way to measure the intensity of competition. Consequently, we consider here two extensions: i) the degree of collusion is captured by the common discount factor and ii) a model of horizontal differentiation with Bertrand competition.

Discount factor

We consider an industry with $N \geq 2$ firms playing an infinitely repeated game producing a quantity of a homogeneous product with production costs normalized to zero at dates $t = 1, ..., \infty$ with a common discount factor $\delta \in [0, 1)$. We assume an industry inverse demand given by the piecewise linear function, $p(Q) = \max(0, 1-Q)$. Following Friedman (1971), we restrict attention to the well-known grim "trigger strategies" in such a way that if a firm defects, the other firm reverts from there on to the static Nash-Cournot quantity, and obtains a profit that we denote by Π^N. For each firm, let q denote the output corresponding to collusion. Each firm producing q corresponds to a SPNE if and only if the following condition is satisfied for each firm:

$$\frac{\Pi^c}{1-\delta} \geq \Pi^d + \frac{\delta \Pi^N}{1-\delta}, \tag{2}$$

where Π^d denotes the one period profit from deviation. There are many subgame perfect Nash equilibria —henceforth, SPNE— collusive output vectors that satisfy the system of inequalities in condition (2) above. As in Verboven (1997) and Escrihuela-Villar (2008a), we select an equilibrium from this large set assuming that if δ exceeds a certain critical level, the set of SPNE vectors is not a binding constraint, and the distribution of output is the symmetric distribution of the output of a monopolist. If δ is below that critical level, then the set of SPNE vectors is a binding constraint, and the distribution of output is the solution to any equality constraint in (2). Let us denote the above mentioned critical level of the discount factor by $\bar{\delta}$. It can be verified that $\bar{\delta} = \frac{(1+N)^2}{1+N(6+N)}$. Then, the equilibrium quantities of each firm q depend on δ. Note that coordination might not be complete according to the fact that firms may agree or not on the monopoly outcome. It can be easily checked that the quantity produced by each firm in the collusive equilibrium, that we denote by $q(N, \delta)$, is given by

$$q(N,\delta) = \begin{cases} \frac{\delta(N-1)(3+N)-(1+N)^2}{(1+N)(\delta(N-1)^2-(1+N)^2)} & \text{if } \delta < \bar{\delta} \\ \frac{1}{2N} & \text{if } \delta \geq \bar{\delta}. \end{cases}$$

Consequently, the market price is given by the following expression:

$$p(N,\delta)=\begin{cases}\frac{\delta-N(2+N-2\delta+3N\delta)-1}{(N-1)^2(1+N)\delta-(1+N)^3} & \text{if } \delta<\bar{\delta}\\ \frac{1}{2} & \text{if } \delta\geq\bar{\delta}\end{cases}$$

where $\delta=0$ represents the Cournot equilibrium and as $\delta\longrightarrow\bar{\delta}$ we obtain the monopoly equilibrium. Consequently, a variation in the discount factor when $\delta\in(0,\bar{\delta})$ can be interpreted as a variation in the degree of collusion of the market. The following result shows that our results carry over to the case where δ captures the degree of collusion.

Proposition 3 *$E_\delta(N,\delta)$ increases with N and $|E_N(N,\delta)|$ decreases with δ. Furthermore, $\forall N\geq 2$ there exists $\delta^*\in(0,\bar{\delta})$ such that $|E_N(N,\delta)|>E_\delta(N,\delta)$ if $\delta<\delta^*$ and $|E_N(N,\delta)|<E_\delta(N,\delta)$ if $\delta>\delta^*$.*

Price competition

We consider the standard oligopoly model with differentiated products where N firms, indexed by $i=1,2,..,N$, produce at zero cost horizontally differentiated products such that the degree of differentiation between the products of any two firms is the same. In other words, the inverse demand function exhibits a Chamberlinian symmetry. In such a differentiated oligopoly thus the environment of each firm is described by his brand demand function

$$p_i=1-q_i-b\sum_{j\neq i}^{N}q_j$$

where p_i denotes the price of good i and q_j the quantity sold of good j. Therefore, N refers also to the number of brands (products) in existence. Alternatively, we can write the demand system as

$$q_i=\alpha-\beta p_i+\gamma\sum_{j\neq i}^{N}p_j$$

where $\alpha=\frac{1}{1+(N-1)b}$, $\beta=\frac{1+(N-2)b}{(1-b)(1+(N-1)b)}$ and $\gamma=\frac{b}{(1-b)(1+(N-1)b)}$.It is assumed $b>0$ where b can be interpreted as the parameter to measure the degree of homogeneity between any two products in the industry. Hence, $b=0$ implies that the products are completely independent and $b=1$ indicates that they are perfect substitutes and therefore the market is perfectly competitive. The value range for b (the common degree of product substitutability) implies that the products are viewed as substitutes rather than complements.

It can be easily checked that the symmetric market price is given by $p(b) = \frac{1-b}{2+b(N-3)}$. The following result also shows that our results carry over to the case where b captures the degree of competition in the market.

Proposition 4 *$|E_b(N,b)|$ increases with N and $|E_N(N,b)|$ increases with b. Furthermore, $\forall N \geq 2$, $|E_b(N,b)| > |E_N(N,b)|$ if $b > \frac{1}{N}$ and $|E_N(N,b)| > |E_b(N,b)|$ if $b < \frac{1}{N}$.*

Proofs

Proof of Propositions 1 and 2. From (1) we obtain that $E_N(N,\lambda) = \frac{bN(\lambda-1)}{(1+(N-1)\lambda)(b+N+b(N-1)\lambda)} < 0$ if $0 \leq \lambda \leq 1$. On the other hand, $E_\lambda(N,\lambda) = \frac{b(N-1)N\lambda}{(1+(N-1)\lambda)(b+N+b(N-1)\lambda)} > 0$. Furthermore, we can easily obtain that $\frac{\partial E_\lambda(N,\lambda)}{\partial N} = \frac{b\lambda(N^2-b(1+N(\lambda-2)-\lambda)(1+(N-1)\lambda))}{(1+(N-1)\lambda)^2(b+N+b(N-1)\lambda)^2} > 0$ and $\frac{\partial E_N(N,\lambda)}{\partial \lambda} = \frac{bN(N^2-b((\lambda-1)^2-2N(\lambda-1)^2+N^2(\lambda-2)\lambda))}{(1+(N-1)\lambda)^2(N+b(1+(N-1)\lambda))^2} > 0$. With respect to Proposition 2, we can easily check that the equation $E_\lambda(N,\lambda) - (-E_N(N,\lambda)) = 0$ has only one root in λ given by $\lambda = \frac{1}{N}$ and that $E_\lambda(N,0) < -E_N(N,0)$. ■

Proof of Proposition 3. We can easily check that $E_\delta(N,\delta) = \frac{-4(N-1)N(1+N)^2\delta}{-(1+N)^4-2(N-1)(1+N)^3\delta+(N-1)^3(1+3N)\delta^2} > 0$ and that $E_N(N,\delta) = \frac{N((1+N)^4+2(1+N)^2(1+(N-6)N)\delta-(N-1)^2(3+N(2+3N))\delta^2)}{-(1+N)^5-2(N-1)(1+N)^4\delta+(N-1)^3(1+N)(1+3N)\delta^2}$. Therefore, $E_N(N,\delta)$ is negative if $\delta = 0$. At the same time we can check that the only root in δ of $E_N(N,\delta) = 0$ in the interval $0 < \delta < 1$ is $\delta = \frac{(1+N)^2(1+(N-6)N)}{(N-1)^2(3+N(2+3N))} + 2\sqrt{\frac{1+N^3(16+N(30+16N+N^4))}{(N-1)^4(3+N(2+3N))^2}} > \bar{\delta}$. On the other hand, $E_\delta(N,\delta)$ is obviously equal to 0 if $\delta = 0$. Then, in order to prove that the degree of collusion elasticity of the market price is positive we only have to check that it increases with δ, that is $\frac{\partial E_\delta(N,\delta)}{\partial \delta} = \frac{4(N-1)N(1+N)^2((1+N)^4+(N-1)^3(1+3N)\delta^2)}{((1+N)^4+2(N-1)(1+N)^3\delta-(N-1)^3(1+3N)\delta^2)^2} > 0$. Also $\frac{\partial E_\delta(N,\delta)}{\partial N} = \frac{4\delta((1+N)^5(3N-1)+2(N-1)^2(1+N)^4\delta+(N-1)^3(1+N)(1+N(4+11N))\delta^2)}{((1+N)^4+2(N-1)(1+N)^3\delta-(N-1)^3(1+3N)\delta^2)^2} > 0$. On the other hand, since $E_N(N,\delta) < 0$ the second part of the result holds as long as $\frac{\partial E_N(N,\delta)}{\partial \delta} = 4N(1+N)(N-1)(\frac{N-1}{((1+N)^2-(N-1)^2\delta)^2} + \frac{2N}{((1+N)^2+(N-1)(1+3N)\delta)^2}) > 0$. Finally, it immediate to verify that $|E_N(N,0)| > E_\delta(N,0) = 0$. Also, we can check that the equation $E_\delta(N,\delta) - (-E_N(N,\delta)) = 0$ has only one root in δ given by $\delta \equiv \delta^* = 2\sqrt{\frac{(1+N)^4(3-10N+8N^2+2N^3+N^4)}{(N-1)^4(3+2N+3N^2)^2}} - \frac{(1+N)^2(6N+N^2-3)}{(N-1)^2(3+2N+3N^2)}$ where $\delta^* < \bar{\delta}\ \forall N \geq 2$. ■

Proof of Proposition 4. Since $E_b(N,b) = \frac{b(N-1)}{(b-1)(2+b(N-3))} < 0$ and $E_N(N,b) = -\frac{Nb}{2+b(N-3)} < 0$, we just have to check that $\frac{\partial |E_b(N,b)|}{\partial N} = \frac{2b}{(2+b(N-3))^2} > 0$ and $\frac{\partial |E_N(N,b)|}{\partial b} = \frac{2N}{(2+b(N-3))^2} > 0$. Finally, $\frac{2N}{(2+b(N-3))^2} > \frac{2b}{(2+b(N-3))^2}$ if $b < \frac{1}{N}$. ■.

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